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MOD-5: A COMPUTER CODE FOR CALCULATIONS OF NEUTRON TIME-ENERGY DISTRIBUTIONS IN THE SLOWING DOWN REGION

by

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ABSTRACT:

This document provides users' information for a computer code, MOD-5, which calculates the time and energy dependent evolution of the neutron density in homogeneous media following initiation of a pulsed neutron source of arbitrary energy distribution. The code is based on a discrete stochastic model of the neutron slowing down process developed by the author. Copies of the code and associated computer software are available through the Argonne Code Center, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439.

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I. PROGRAM DESCRIPTION

Introduction

MOD-5 is a FORTRAN IV computer code utilizing a discrete stochastic model to obtain numberical solutions to the space independent neutron slowing down equation. The nucleus of the model is a "population vector" whose components are defined over a set of discrete energy states and specify the fraction of the total neutron population lying in a given state at a given time. The population vector may be advanced forward in discrete time steps by multiplication into a suitably designed one-step transition matrix. The method is rather similar to models devised by Perkel (1) and by Ohanian and Daitch (2) but has several unique features which greatly extend the capability of this approach.

Detailed discussions of the model may be found in two papers which have been included in this report (3,4) as Appendicies A and B, and the reader is urged to be thoroughly familiar with these before attempting to use MOD-5. Some useful information is also available in a doctoral dissertation based on this model (5), however many significant changes have been made since the dissertation was completed.

Specifics of the model will not be examined further here. This report is concerned only with providing technical information (a) about the structure and operation of the code, and (b) the mechanics of setting up typical problems for analysis by MOD-5.

Classes of Problems that May be Studied with MOD-5

MOD-5 evaluates numerical representation of time and energy dependent solutions of the slowing down equation following initiation of some sort of pulsed source. In its present configuration the following source conditions are available in MOD-5:

(a) Delta function in energy, delta function in time.

(b) Fission spectrum in energy, delta function in time.

(c) Arbitrary energy spectrum, delta function in time.

(d) Delta function in energy, uniform distribution over some small time interval.

A variety of functions and parameters are calculated by MOD-5. Among the more important are:

(a) Spectra (lethargy dependent neutron density) and energy moments at selected times following initiation of the source,

(b) Time dependent neutron density and slowing down density at selected energies and time moments of these densities,

(c) Time dependent distributions of times to capture, leakage, and first fission, and moments of these distributions,

(d) Steady state central core neutron flux and leakage flux in detail and group averaged form, and

(e) Miscellaneous parameters such as k_{eff}, capture probability, etc.

Organization of the Program

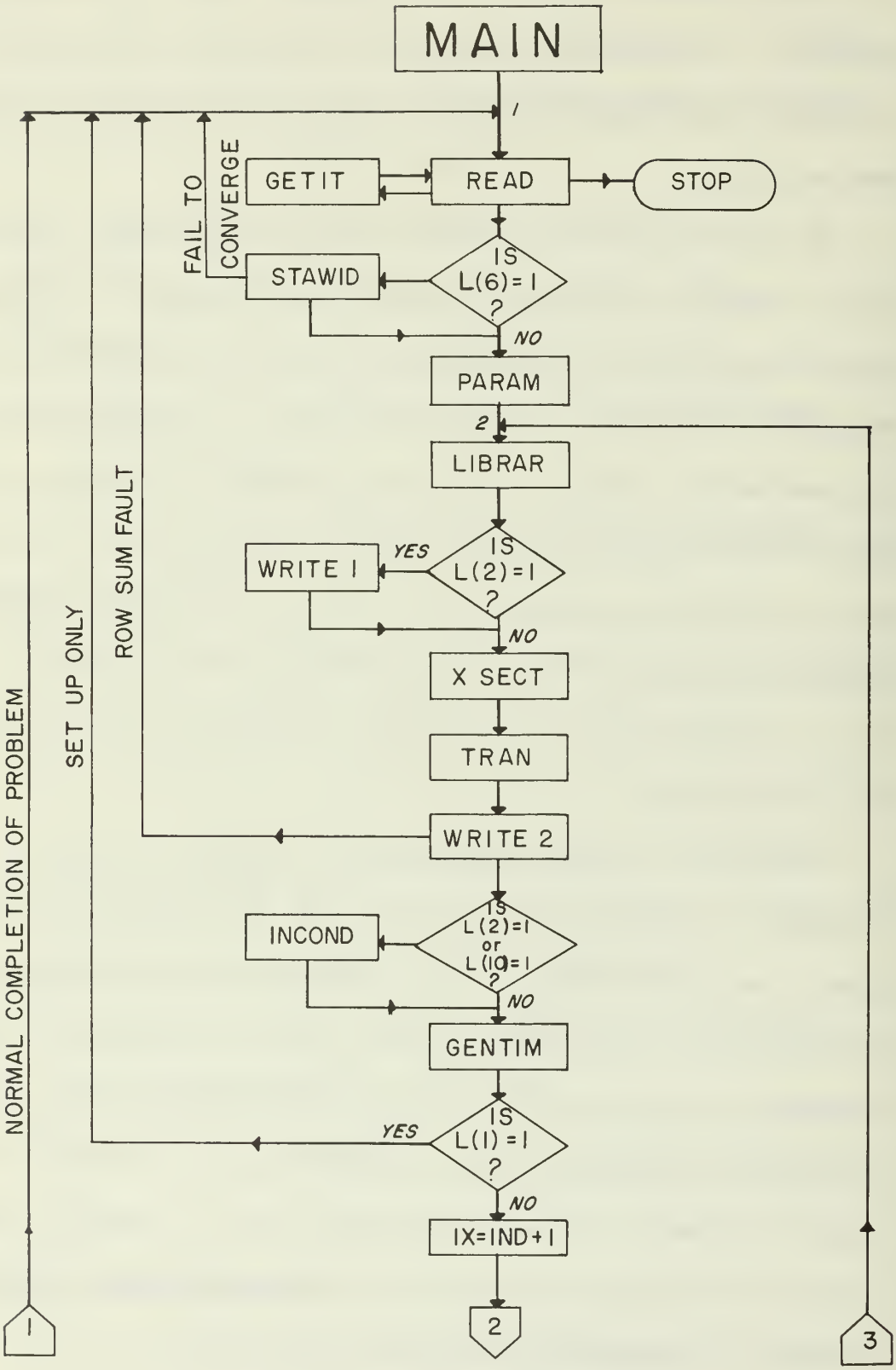
MOD-5 consists of a control program MAIN and 20 subroutines of

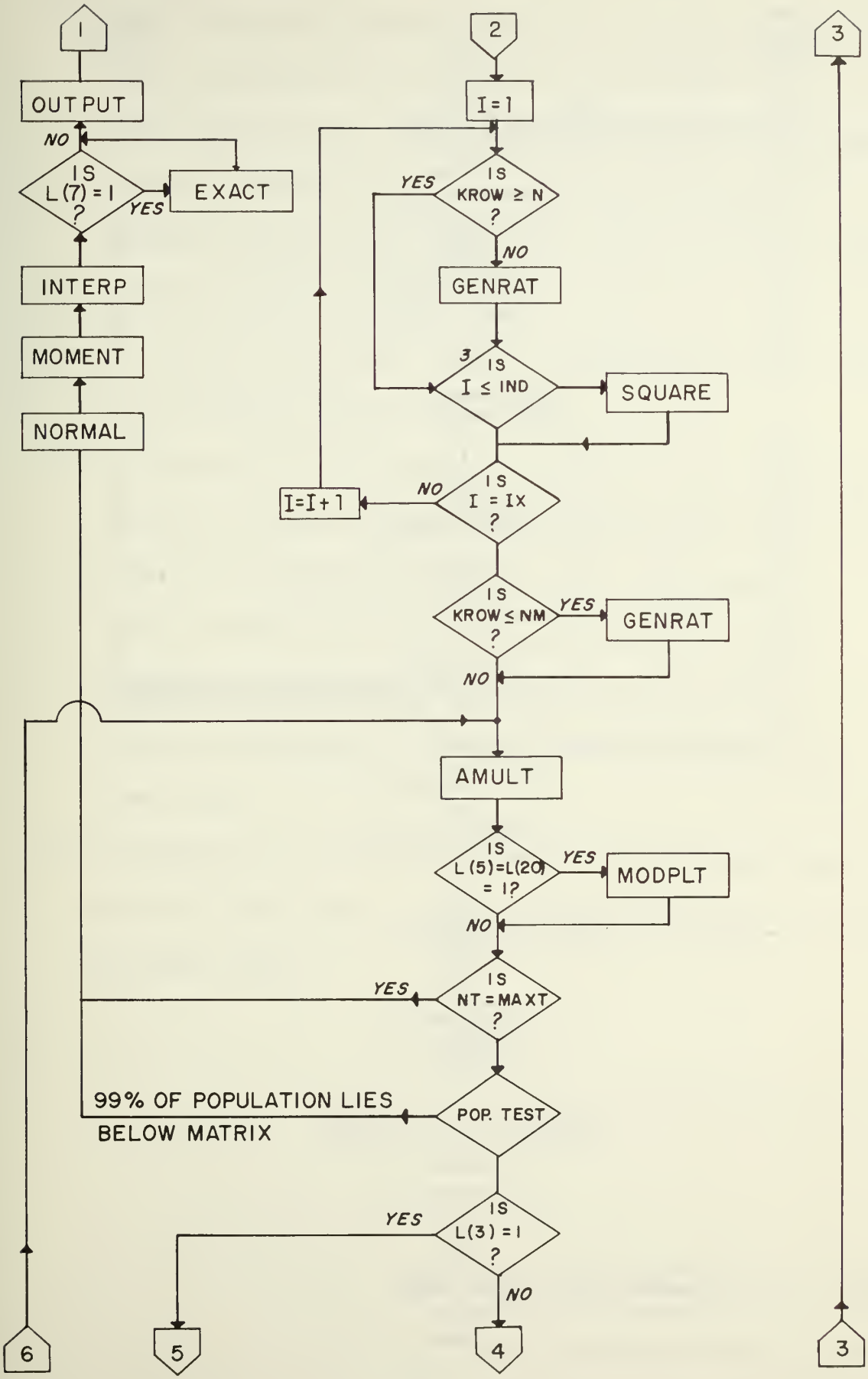
which all but one (GETIT) are called from MAIN. The flow of control is shown schematically in Figure 1 and a complete listing may be found in Appendix F. A description of the function of each subroutine may be found in Appendix E with elaborations in the comment cards included in the program listing.

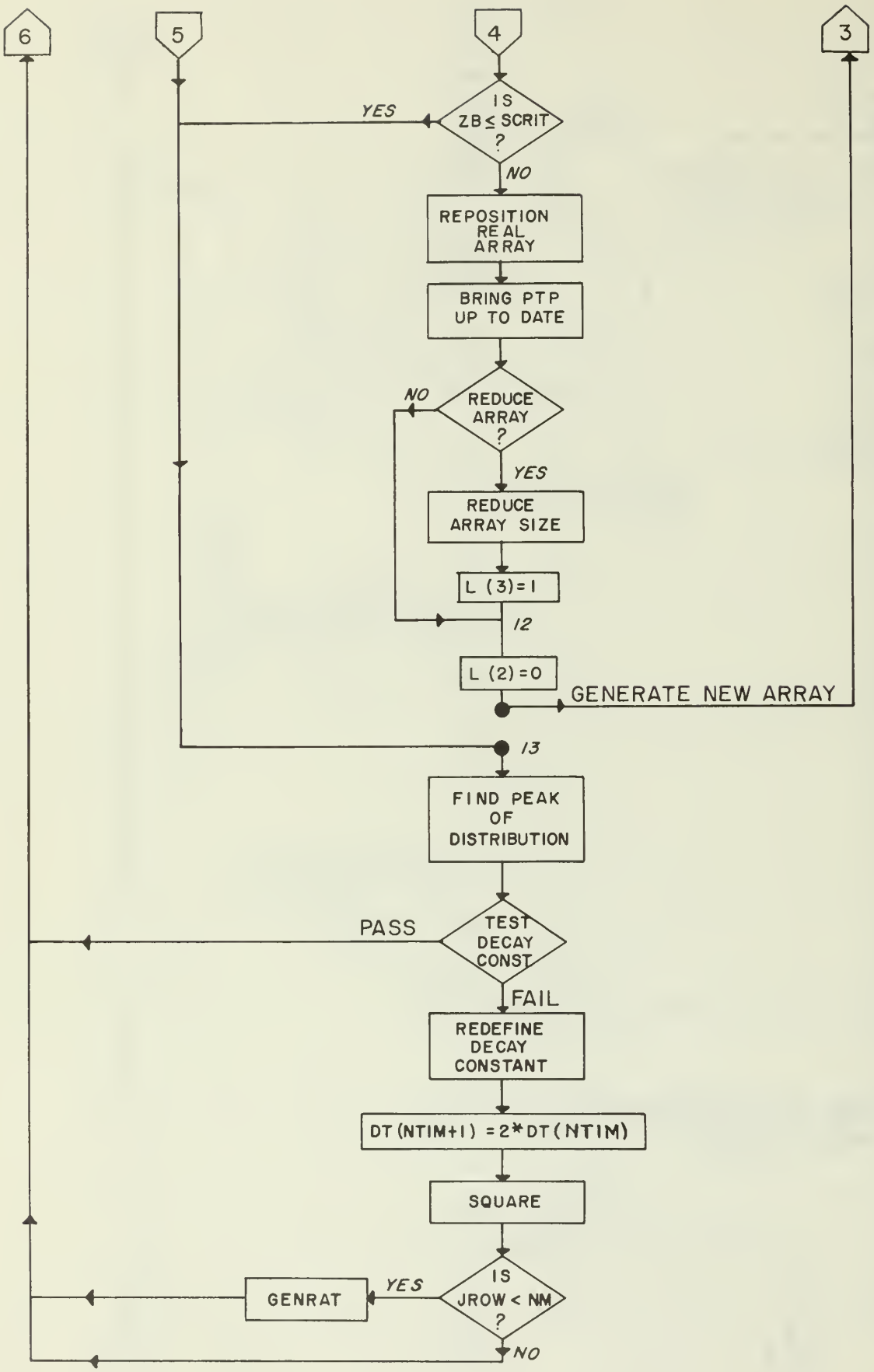
All input data enters via READ (on cards) or GETIT (disk or tape files of cross sections). Subroutines STAWID through INCOND in the calling sequence are concerned with processing cross sections and other data do define state parameters, transfer coefficients $p_{i,j}$, and initialization of the state vector. GENTIM selects appropriate transition matrix generating times and operating time steps (δt and Δt respectively in Eqs. 44-46 of App. A). SQUARE and GENRAT work together in a DO loop to generate a stepping matrix defined for Δt. AMULT multiplies the population vector into the stepping matrix to produce a new population vector defined for a time one step later.

After AMULT is called MAIN performs a series of operations to determine the progress of the neutron density, and selects one of several paths in the control sequence. If the desired number of operating iterations (multiplications of the population vector into the transition matrix) has been completed, or if at least 99% of the population lies below the energy range of interest or in capture, fission or leakage states, the evolution of the population vector is terminated and control goes to a series of routines that process the data for output listing (NORMAL-OUTPUT). Otherwise the matrix is evaluated for one of three possibilities:

FIGURE 1.


MAIN
1
GETIT
READ
STOP
FAIL TO CONVERGE
STAWID
IS L(6)=1 ?
NO
PARAM
2
LIBRAR
WRITE 1
YES
IS L(2)=1 ?
NO
X SECT
TRAN
WRITE 2
INCOND
IS L(2)=1 or L(10)=1 ?
NO
GENTIM
YES
IS L(1)=1 ?
NO
IX=IND+1
2
NORMAL COMPLETION OF PROBLEM
SET UP ONLY
ROW SUM FAULT
1
3


1
OUTPUT
NO
IS L(7) = 1 ?
YES
EXACT
INTERP
MOMENT
NORMAL
2
I = 1
YES
IS KROW ≥ N ?
NO
GENRAT
3
IS I ≤ IND
SQUARE
I=I+1
NO
IS I = IX ?
IS KROW ≤ NM ?
YES
GENRAT
NO
AMULT
IS L(5)=L(20) = 1?
YES
MODPLT
NO
YES
IS NT = MAXT ?
99% OF POPULATION LIES BELOW MATRIX
POP. TEST
YES
IS L(3) = 1 ?
NO
6
5
4
3


6
5
4
3
IS ZB ≤ SCRIT ?
YES
NO
REPOSITION REAL ARRAY
BRING PTP UP TO DATE
REDUCE ARRAY ?
NO
YES
REDUCE ARRAY SIZE
L (3) = 1
12
L (2) = 0
GENERATE NEW ARRAY
13
FIND PEAK OF DISTRIBUTION
TEST DECAY CONST
PASS
FAIL
REDEFINE DECAY CONSTANT
DT (NTIM+1) = 2*DT (NTIM)
SQUARE
IS JROW < NM ?
YES
NO
GENRAT

(a) If the real operating matrix does not lie at the bottom of the virtual operating matrix (See App. B and C for definitions of these terms) the real matrix is evaluated to see whether it should be moved downward in energy. This shift is performed if a fraction SCRIT of the total population has been slowed down below the lower energy boundary of the real matrix. In this event the new position and size of the matrix is determined and then control is transferred to statement 2 in MAIN.

(b) Next MAIN tests to see whether the operating time step should be doubled to compensate for decreasing collision rates as the population moves downward in energy. If it is to be doubled the matrix is squared by SQUARE. At this point new rows can be added to an incomplete matrix by GENRAT if the probability for a collision in Δt for each row ($v\Sigma_t \Delta t$) exceeds CRIT (DEFAULT value 0.001)

(c) If the matrix is not shifted downward in energy, control is finally returned to AMULT for another operating iteration on the population vector.

II. USERS INFORMATION

Restrictions on Complexity of the Problem

Almost all of the variables in MOD-5 have been included in a COMMON block. The list below reflects the restrictions imposed by the COMMON block that appears in the program listing in Appendix F. The program has been adapted to handle up to 701 virtual states and 201 real states in a problem with a single isotope simply by replacing the existing COMMON blocks with an appropriately modified form.

Max. number of isotopes	5
Max. number of real energy states	71
Max. number of virtual energy states	201
Max. number of broad groups for input cross sections	26
Max. number of time steps	400
Max. number of time moments	21
Max. number of groups from which inelastic scattering can take place	10

Running Time

On the IBM 360 the execution time in seconds is given approximately by the formula

$$t = 0.004\ N\ N_v + 10$$

where N is the number of real states and N_v is the number of virtual states

Basic Data Deck Format

The input data to MOD-5 requires a minimum of 6 data cards.

CARDS 1 - 3 Provide for a title block. FORMAT 18A4

CARD 4 A listing of initial values of the control variable L (Appendix D). Note that column 4 (L(2)) must always

have a "1" punch and column 24 (L(12)) must always have a "0" punch. FORMAT 30I2

CARD 5 — A listing of numbers locating the desired isotopes in the external cross section file. The isotopes may be listed in any order at input but will be rearranged by subroutine READ in order of increasing atomic mass (exception: hydrogen is always placed last in the list). FORMAT 5I5

(at this point in the program cross sections are retrieved from the disk or tape file)

CARDS 6 - n — NAMELIST NUMBRS. A list of the variables that can be read in under NUMBRS can be found in the listing of subroutine READ. DEFAULT values of these variables may be found in the Glossary (Appendix C) or in READ. Note that the position of values assigned to such variables as RHO, SCALE, (i.e. all variables for which one dimension specifies the isotope) must be determined by the order of the isotope numbers on CARD 5.

Cross Sections

MOD--5 has been provided with a library of the Russian 26 group cross section set (6). Cross sections, inelastic scattering transfer matrices, and 300°K resonance self shielding coefficients are included for the 40 isotopes and 3 fission fragment sets listed below. The cross sections presumably will be stored by the user on disk or tape and are retrieved by subroutine GETIT. The numbers below are used on CARD 5 to specify the desired cross section sets. Auxiliary program SLOAD (Appendix G) should be used to load the external files in the correct format.

1. hydrogen	15. potassium	29. lead
2. deuterium	16. calcium	30. bismuth
3. lithium-6	17. titanium	31. thorium-232
4. lithium-7	18. vanadium	32. U-233
5. beryllium	19. chromium	33. U-234
6. boron-10	20. iron	34. U-235
7. boron-11	21. nickel	35. U-236
8. carbon	22. copper	36. U-238
9. nitrogen	23. zirconium	37. Pu-239
10. oxygen	24. niobium	38. Pu-240
11. sodium	25. molybdenum	39. Pu-241
12. magnisium	26. tantalum	40. Pu-242
13. aluminum	27. tungsten	41. U-233 Fiss.Frags.
14. silicon	28. rhenium	42. U-235 Fiss.Frags.
		43. Pu-239 Fiss.Frags.

Sample Problems

Portions of the output listings for the following examples may be found in Appendix H.

```
EXAMPLE NUMBER 1
     EVALUATION OF ASYMPTOTIC SOLUTION TO SLOWING DOWN EQUATION.
     INFINITE HOMOGENEOUS MODERATOR.  DELTA SOURCE IN TIME AND ENERGY.
0 1 1 1 0 1 1 0 0 0 1 0 0 1
 8
&NUMBRS N=51,NVIR=51,NMX=8,NMOM=1,2,3,4,5,-1,-2,-3,RHO=1.64,
   (50)=1.00,SIGTE=26*4.7,SIGSB=26*0.,SIGNB=26*0.,SIGCB=26*0.,
   SIGTB=26*4.7,AMUB=26*0.05556,E=144*0.,FSS=3120*1.,&END
```

Comments:

CARD 4	L(3)=1	because N=NVIR (CARD 6)
	L(4)=1	because it is desired to study the time dependence of the neutron density at E(NM)
	L(6)=1	The state widths will be chosen to provide an optimal description of elastic scattering. See description of STAWID in App. F.
	L(7)=1	To compare calculated and theoretical time moments.
	L(8)=L(9)=0	Because L(11)=1
	L(11)=1	Delta function source
	L(12)=0	Required input value, this variable is redefined internally

	L(15)=1	A listing of the time dependent neutron density at EII(NM) and slowing down density at E(NM) will be printed in OUTPUT.
CARD 5	NOLIST(1)=8, NOLIST(2)=0,etc.	Cross sections for carbon will be retrieved from the external file. No other isotopes are present.
CARD 6	N=51	51 real states
	NVIR=51	51 virtual states
	NMO=8	8 time moments will be evaluated to orders listed in NMOM
	RHO=1.64	Nominal mass density of graphite (gm/cc)
	E(50)=1.00	Lowest energy of interest is 1.00 eV.
	SIGTB=26*4.7, etc	Cross sections from external files are replaced with an idealized set in which there is only elastic scattering and the cross section is independent of energy.

PERTINENT DEFAULT VALUES ASSUMED

NI=1	one isotope
NF=0	no fissionable isotopes
NSCAT=1	Stawid is called (because L(6)=1) and will optimize for scattering into one lower energy state.
MAXT=400	If necessary, the population vector can be evaluated for 400 time steps
CRIT=.001	Normally user will not need to override DEFAULT values of CRIT OPCRIT, SQCRIT, SCRIT and CONVC. The chosen values are based on operating experience.

```
EXAMPLE NUMBER 2
      STUDY OF SLOWING DOWN OF NEUTRONS FROM A 0.5 MICROSECOND, 2.46
      MEV PULSED SOURCE (0,0).  DEMONSTRATES TRAVELING ARRAY.
1 0 0 0 1 1 0 1 0 0 0 0 0 1 0 0 1
  8
NUMBRS NVIR=109,NSCAT=2,OPCRIT=0.5,SQCRIT=0.25,TIMWID=0.5E-06,RHO=1.64,
E(1)=2.46E 06,&END
```

Comments:

CARD 4	L(3)=0	because N<NVIR, the real transition matrix will follow the pulse as it moves downward in energy.

	L(4)=0	In this problem the evolution of the neutron distribution from the source is of special interest.
	L(9)=1	The source simulates a d(d,t)n pulsed source with a delta-function distribution in energy and a uniform 0.5 microsecond distribution in time (specified on CARD 6)
	L(11)=0	Complementary to L(9)=1
	L(18)=1	In addition to printing interpolated time distributions the program will print DENS and SDENS at every operating time step.
CARD 5		Same as Example 1
CARD 6	NSCAT=2	The distribution of neutrons following an elastic collision spans two lower energy states (optimized in STAWID)
	NVIR=109	With this many states the energy range 2.46 MeV to 1.0 eV is spanned.
	OPCRIT=0.50 SQCRIT=0.25	Increasing the values of these parameters increases the operating time step widths proportionately. In this problem MAXT=400 is not adequate to allow a run to completion unless OPCRIT and SQCRIT are increased.
	E(1)=2.46E 06	Since L(4) = 0, E(1) must be specified or a DEFAULT value of 10.5 MeV will be assigned.

The DEFAULT option for cross sections is to load from the external file.

```
EXAMPLE NUMBER 3
     STUDY OF SLOWING DOWN SPECTRA IN REPRESENTATIVE FAST MULTIPLY-
     ING ASSEMBLY.  FISSION SOURCE - DELTA FUNCTION IN TIME.
0 1 0 0 1 0 0 0 0 1 0 0 0 0 1
  34   36   20   13
&NUMBRS NVIR=121,NI=4,NF=2,EHI=2.622,3.016,.965,.848,BUCKLE=0.0072,
 DU(2)=119*0.05,SCALE=52*.1,26*.5,&END
```

This problem analyzes various time dependent processes in a fast multiplying system. Steady state properties are derived by integrations over time

CARD 4	L(4)=0	E(1) must be specified, in this case a DEFAULT value of 10.5 MeV will be used since no other value is specified in NUMBRS (10.5 MeV is the upper energy limit of the 26 group cross section set).
	L(6)=0	STAWID is not called. Should L(6)=1 STAWID would be called and the state structure would be optimized for the isotope of smallest mass (generally also of the greatest moderating power)
	L(8)=L(9)= L(11)=0	By DEFAULT a fission spectrum source, delta function in time, will be defined.
	L(12)=0	This will be redefined to L(12)=1 in subroutine XSECT because there are inelastic scattering isotopes present.
CARD 5		The first isotope on the input data set is number 34 in the external file (U-235), the second is number 36 (U-238), etc. READ will rearrange these in ascending numerical order.
CARDS 6-7	NI=4	Four isotopes in the system
	NF=2	Two of the isotopes are fissionable
	RHO(1)=2.622, 3.016,···	The density of U-235 is 2.622 gm/cc, of U-238 is 3.016 gm/cc, etc. These numbers appear in an order consistent with the list on CARD 5 and will also be rearranged by READ.
	BUCKLE=0.0072	Geometric buckling
	DU(2)=119*.05	Because STAWID is not called, the lethargy widths (or boundary values) must be specified for all states. IMPORTANT: For the user's convenience the lethargy at input is specified to log base 10 and then converted to base e internally. Thus the specification DU=0.05 provides 20 states per decase. Note that although the state widths are uniform in these examples they need not be in general. DU(1)=0 and DU(N)=1.E06 by DEFAULT always and need not be specified.

```
SCALE(1)=26*0.1,
26*0.1,26*0.5
```

The mean lethargy increment per elastic collision is less than the state widths for U-235, U-238 and iron. Scale factors of 0.1, 0.1, and 0.5, respectively, ensure that the energy distribution of scattered neutrons extends into the next lower energy state. For aluminum the DEFAULT scale factor of 1.0 is assumed.

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6. L. P. ABAGYAN, N. O. BAZAZYANTS, I. I. BONDARENKO and M. N. NIKOLAEV, Group Constants For Nuclear Reactor Calculations, Consultants Bureau, New York (1964).

Other Related References

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T. J. WILLIAMSON and R. W. ALBRECHT, Proc. Conf. on Fast Reactor Physics, Vol. 1, Karlsruhe, Published by the International Atomic Energy Commission, Vienna 1968, pp. 513-528.

APPENDIX A

(pages 19 - 36 inclusive)

APPENDIX B

(pages 38 - 42 inclusive)

NUCLEAR SCIENCE AND ENGINEERING: 42, 89-111 (1970)

Technical Notes

Calculations of Neutron Time-Energy Distributions in Heavy Moderators

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The task of making detailed neutronics calculations for heavy moderating isotopes has always been a most difficult problem for a variety of reasons. Consider, for instance, the problem of calculating the time and energy (or lethargy) dependent neutron density $N(E,t)$ that develops in a homogeneous moderator during and following the introduction of a source, $S(E,t)$ in the MeV range. Monte Carlo techniques are very impractical because of the large number of collisions required per history. The usual multigroup stepping matrix techniques[1] are inapplicable for at least two reasons: (a) inordinately large matrices are required when collision energy losses are small and (b) scattering through the inelastic region may take but a microsecond while moderation to thermal energies may require times of the order of a millisecond, thus making it virtually impossible to choose a suitable time step upon which to define the matrix.

Analytical techniques[2,3] have been reasonably successful in predicting the low energy or asymptotic shape of $N(E,t)$ but they are incapable of dealing with the complexity of inelastic scattering, the effects of which carry over to relatively low energies.

We have been able to overcome many of these difficulties using our recently developed discrete stochastic model.[4] The model is similar in many respects to the usual time-dependent multigroup theory in which a multigroup neutron spectrum, represented here by a state vector $\bar{s}(t)$

$$\bar{s}(t) = [s_1(t), s_2(t), \ldots,] \tag{1}$$

is stepped forward in time by repeated multiplication into a stepping matrix $\bar{\bar{P}}_{\Delta t}$

$$\bar{s}(t + \Delta t) = \bar{s}(t) \cdot \bar{\bar{P}}_{\Delta t} \quad , \tag{2}$$

where the elements $P_{i,j}(\Delta t)$ of $\bar{\bar{P}}_{\Delta t}$ are probabilities for transition between groups i and j during the interval Δt, and $s_i(t)$ is the population of group i. The new model differs from multigroup theory in the method of calculating transition probabilities and in the use of a well-known result of the theory of Markov processes which allows the stepping interval to be conveniently increased

$$\bar{\bar{P}}_{n\Delta t} = (\bar{\bar{P}}_{\Delta t})^n \tag{3}$$

Equation (3) provides a mechanism for the generation of a stepping matrix with transition probabilities of consistent accuracy for any step and energy range.

A requirement for maximum accuracy in multigroup calculations of elastic scattering processes is that the groups be small enough to allow neutrons to scatter from the mean scattering energy in one group to the smallest energy of the next lower group. For moderating isotopes with mass $A \sim 200$ this requires at least 160 groups per decade in energy. Unfortunately, on most computers a stepping matrix of dimension 200×200 represents a practical upper limit (both in terms of computation time and storage requirements) while typical slowing down problems span four or more decades.

We have circumvented this restriction by allowing the stepping matrix to cover only that region of energy occupied by the neutron population at a given instant. It is a well-known result of collision theory[5] that with purely elastic scattering the asymptotic energy distribution of moderating neutrons is nearly Gaussian with a dispersion (relative standard deviation) no larger than

$$D = \left[\frac{\langle E^2\rangle - \langle E\rangle^2}{\langle E\rangle^2}\right]^{1/2} = \left(\frac{8}{3A_L}\right)^{1/2} \quad , \tag{4}$$

where A_L is the atomic mass of the lightest isotope present. As the neutron population moves downward in energy following a short burst from the source, we allow the matrix to move with it using the previously mentioned technique to generate new rows of transition probabilities at the bottom of the matrix, and to increase time steps as appropriate (Fig. 1). In the calculation described below, a real matrix of dimension 200×200 was carried down the diagonal of a "virtual" (elements not stored in computer) matrix of dimension 700×700.

To reduce calculation times we have used the fact that in the elastic scattering region, transition probabilities decrease geometrically along a row moving away from the diagonal. As a result, for almost any useful time step and any moderator with $A > 10$, the transition probability

[1] A. K. GHATAK and H. C. HONECK, *Nucl. Sci. Eng.*, **21**, 227 (1965).

[2] R. E. MARSHAK, *Rev. Mod. Phys.*, **19**, 185 (1947).

[3] A. A. BERGMAN et al., *Proc. First Intern. Conf. Peaceful Uses At. Energy*, **4**, 135 (1955).

[4] T. J. WILLIAMSON and R. W. ALBRECHT, *Nucl. Sci. Eng.*, **37**, 41 (1969).

[5] K. H. BECKURTS and K. WIRTZ, *Neutron Physics*, p. 174, Springer-Verlag, New York (1964).

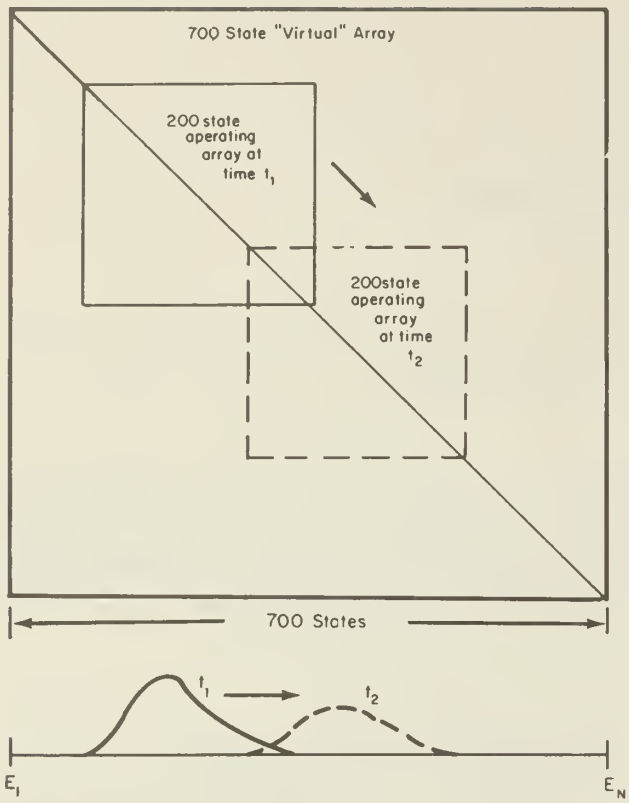

Fig. 1. Scheme for allowing transition matrix to follow neutron population.

$P_{i,j}(\Delta t)$ becomes vanishingly small (say $< 10^{-6}$) if $j > i + 10$. Thus, when calculations are being performed it is unnecessary to include transitions to a state j from any state i that is more than 10 states above j.

Application of our model does require two important compromises. The lesser of the two is the assumption of a normal mode space dependence. This is somewhat justified by the long mean-free-paths characteristic of heavy moderators. The more important compromise is made necessary because of the cooperative effect of inelastic scattering and time distributed sources in dispersing the neutron distribution. Inelastic scattering alone will cause neutrons from a 14 MeV source to be spread out to below 100 keV within a few nanoseconds. Once they are below the inelastic threshold the neutrons lose energy far more slowly and the narrow asymptotic shape is developed after a few collisions. However, because of the initial dispersal of neutrons over the broad inelastic region it is impossible to provide a matrix large enough to treat elastic scattering properly. Instead a few relatively broad groups must be used to span the energy region in which inelastic scattering reactions are the dominant moderating process. Within this region the elastic scattering kernel is adjusted by a scaling process that has been described elsewhere.[4] We have found that scaling tends to artificially disperse the energy distribution without significantly altering the mean energy. Since the inelastic kernel overwhelmingly dominates the shape of the distribution, scaling of elastic cross sections introduces only very minor errors.

As an example of the application of the model to heavy moderators we have chosen to study the lead slowing down spectrometer. Such devices have been in use for several years, in Russia,[3] in Germany,[6,7] and elsewhere. Lead spectrometers usually have a simple configuration such as a large lead cube resting on a concrete pedestal and penetrated by a 14 MeV pulsed neutron source and a small sample channel. If the source pulses are of short duration the neutrons will eventually develop a relatively narrow distribution in energy and the mean energy of the distribution can be easily related to elapsed time. By observing the time dependence of the emission of capture gammas from the sample being studied one can deduce the energy dependence of cross sections. Popov and others have made a number of studies of (n,γ) cross sections by this means.[8-11] More recently, there has been active study of temperature effects on the energy dependence of (n,γ) cross sections of various fast reactor materials.[7] Such studies are considered a necessary adjunct to the analysis of integral Doppler experiments and the theoretical analyses of uncertainties in nuclear data.

Two physical properties of a given spectrometer must be known before it is possible to extract cross sections from reaction rates and determine the accuracy of the estimates.

First it is necessary to know the mean energy of the neutrons as a function of the time elapsed from initiation of the neutron burst. It is easy to show that with a source that is a δ-function in time and velocity, and with a purely scattering medium of atomic mass A and scattering cross section Σ_s, the mean energy $\langle E(t) \rangle$ is given by[3,7]

$$\langle E(t) \rangle = \frac{M_N A^2}{2\Sigma_s^2} \frac{1}{\left(t + \frac{A}{v_0 \Sigma_s}\right)^2} , \qquad (5)$$

where v_0 is the source neutron velocity and M_N is the neutron mass. Although the above result is based on a highly idealized model, our calculations have shown that it works very well over the entire energy range below the inelastic threshold. With realistic source burst widths of up to 4 μsec the formula has been found to be satisfactory if t is replaced by elapsed time from mean emission time.

A far more difficult problem is posed by the desire to know something about the energy or lethargy distribution of the neutrons as time elapses. For most purposes it is sufficient to determine the relative standard deviation in energy (also commonly referred to as dispersion, or resolution) of $N(E,t)$ as a function of either the mean energy or the elapsed time. Clearly this parameter will determine the energy resolution of measured cross sections. Seufert and Stegemann[7] have concluded that for their Doppler measurements it is necessary that

$$\frac{\Gamma_\gamma}{\langle E \rangle} \ll \frac{\overline{D^s}}{\langle E \rangle} \ll D \ll | , \qquad (6)$$

where $\overline{D^s}$ is the mean level spacing, Γ_γ is the gamma width of the resonances, and D is the dispersion of the neutrons [Eq. (4)].

[6] H. SEUFERT, "Untersuchung des Dopplereffektes in schnellen Neutronenspektren nach neuen experimentellen Methoden," Dissertation, Karlsruhe (1968).

[7] H. SEUFERT and D. STEGEMANN, Institute für Neutronenphysik und Reaktortechnik, KFK-631, Kernforschungszentrum, Karlsruhe (1967).

[8] A. I. ISAKOV, YU. P. POPOV, and F. L. SHAPIRO, *J. Exptl. Theor. Phys.*, (USSR), **38**, 989 (1960).

[9] N. T. KASHUKEEV, YU. P. POPOV, and F. L. SHAPIRO, *J. Nucl. Energy*, **14**, 76 (1961).

[10] YU. P. POPOV and F. L. SHAPIRO. *Sov. Phys. JETP*, **15**, 683 (1962).

[11] S. A. ROMANOV and F. L. SHAPIRO, *Sov. J. Nucl. Phys.*, **1**, 2, 159 (1965).

Our calculations have employed the 26-group ABN cross-section set[12] with an additional group added to cover the region from 10.5 to 14 MeV. The few resonances that occur in lead were ignored since they will not affect dispersion calculations significantly. The broad group cross sections were distributed over a fine group structure consisting of about 14 groups per decade above 300 keV and about 159 groups per decade below 300 keV. A geometric buckling of $B^2 = 0.000558$ corresponds to the physical dimensions of a large spectrometer (2.3 m on a side) but ignores such complications as the albedo of the concrete pedestal it sits on.

Output from the calculations consisted of (a) the neutron density in lethargy $N(u,t)$ and the relative standard deviation in energy and velocity at selected times following the initiation of the source, (b) time-dependent capture and leakage rates, and (c) steady-state flux.

The calculation was terminated when the neutrons reached 20 eV, at which point 75.7% had been lost to leakage, 12.2% had been captured in the lead and 12.1% were still slowing down.

Figure 2 displays the calculated lethargy-dependent neutron densities following source pulses of 0, 1, 2, and 4 μsec duration. Certain features of these figures are worth noting:

1. In Fig. 2a the structure and boundaries of the cross-section set are quite apparent. At 2 and 8 nsec the spectrum is almost completely determined by inelastic transfer from the source group.

2. In Figs. 2c and 2d a steady-state situation exists above 200 keV at the time the source is turned off.

3. A striking feature in all four cases is the rapidity with which a Gaussian shape is achieved by the population below 100 keV.

4. An estimate of the relative widths of the distributions at a given time is provided by the heights of the curves. Since the areas under the curves should be about the same at a given time (presuming the source is off) the width of the curve, or equivalently D, will vary inversely as the height. Thus at 50 μsec the distribution from a 4 μsec source is about 20% broader than that from a 1 μsec source.

A more complete description of the resolution of the pulses as a function of energy and elapsed time is given in Fig. 3. Here the abscissa is actually the ratio of D to its asymptotic value.

On the same figure we have plotted for comparison the

[12] L. P. ABAGYAN, N. O. BAZAZYANTS, I. I. BONDARENKO, and M. N. NIKOLAEV, *Group Constants for Nuclear Reactor Calculations*, Consultants Bureau, New York (1964).

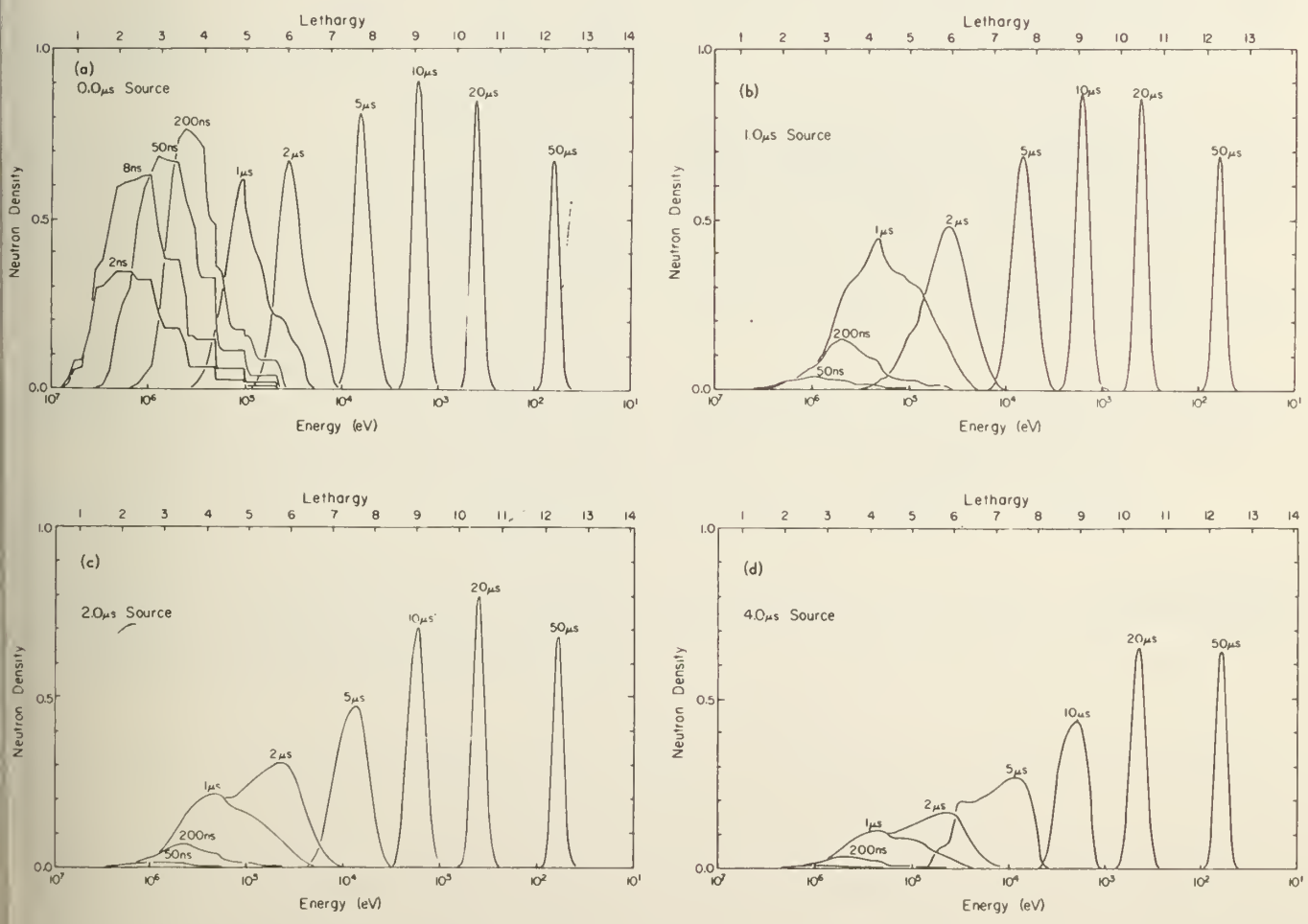

Fig. 2. The function $N(u,t)$ for source burst widths of 0, 1, 2, and 4 microseconds. Normalized to one source neutron at 14 MeV.

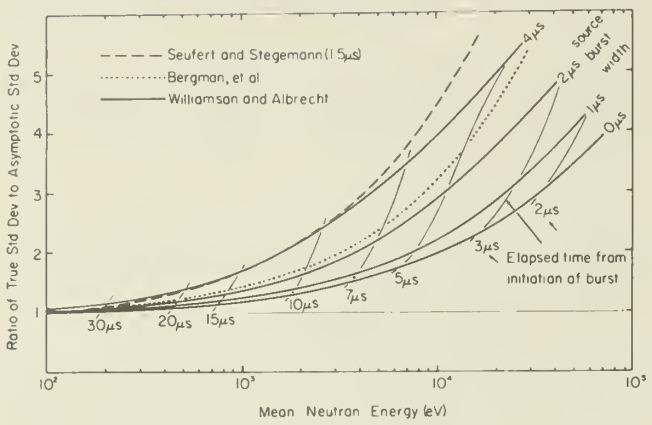

Fig. 3. Ratio of true to asymptotic value of relative standard deviation of $N(E,t)$ as a function of source burst width, mean energy, and time elapsed from initiation of source burst.

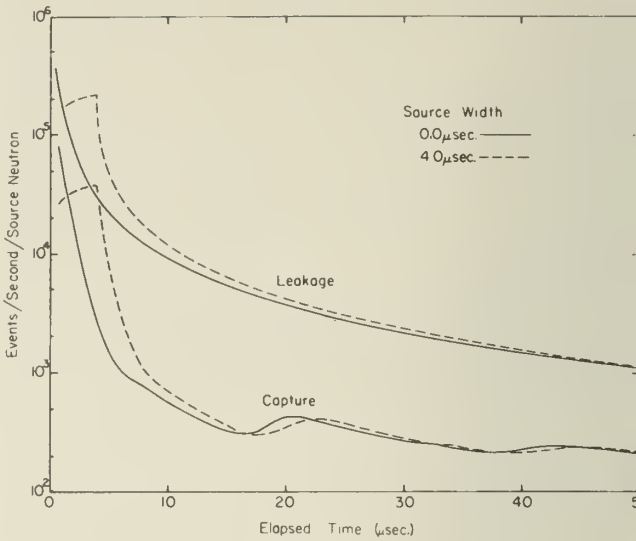

Fig. 4. Time dependence of leakage and capture for 0 and μsec sources.

prediction given by Bergmann et al.[3] (source time unspecified) and by Seufert for a 1.5 μsec source. Our results clearly provide a more optimistic estimate of the resolution of the spectrometer. Seufert's results are based on a model first proposed by Bergmann who suggested that the relative standard deviation in velocity ought to obey the following equation below 100 keV[a]:

$$\left[\frac{\langle v^2\rangle - \langle v\rangle^2}{\langle v\rangle^2}\right]^{1/2} = \left[\frac{2}{3A}\left(1 - \frac{\langle E\rangle}{E_0}\right) + D_0\frac{\langle E\rangle}{E_0}\right]^{1/2}, \qquad (7)$$

where $\langle E\rangle$ is the mean energy, E_0 = 100 keV and the constant D_0 was estimated to be ~0.3. The theoretical basis for this expression is obscure. In fact, in light of recently developed expressions for the lethargy dependence of velocity moments we would expect a better formulation to be a power series in $\left[\frac{\langle E\rangle}{E_0}\right]^{1/2}$.[13] As a useful approximation however, the following expression provides results that compare well with calculations:

$$\left[\frac{\langle v^2\rangle - \langle v\rangle^2}{\langle v\rangle^2}\right]^{1/2} = \left[\frac{2}{3A} + D_0\left(\frac{\langle E\rangle}{E_0}\right)^{0.84}\right]^{1/2}, \qquad (8$$

where, again, E_0 = 100 keV, but D_0 is ~0.07 for source widths of less than 1 μsec. The much smaller value of D is a consequence of the very rapid focusing of the distribution below the inelastic threshold, a fact that is certainly not intuitively obvious.

In practical applications of the spectrometer one of the overriding factors is the existence of background radiation mainly from capture gammas produced in the lead. In Fig. 4 the specific capture rate following 0 and 4 μsec bursts has been plotted. Consistent with reports of experimenters, a high background should persist for up to 5 μsec following the burst.

In closing, it should be noted that certain errors are inherent in the calculation and these are summarized below.

In a previous paper[4] it was shown that generally multigroup calculated dispersions will be larger than the true values. With the optimized stochastic model D is about 5% too large at all energies; however, this error cancels out almost completely in the ratios plotted in Fig. 3.

The leakage rates in Fig. 4 are probably pessimistically large early in the history of the pulse. This is because neutrons are actually born near the center of the cube rather than in a fundamental mode. Clearly a neutron born at the center has a smaller probability for leakage during its lifetime than one born elsewhere. Because of the overestimate of leakage we would expect that the distribution in Fig. 2 should properly have slightly greater amplitude.

[a] Our numerical calculations have shown that the following relation seems to hold true at all energies:

$$\frac{\langle v^2\rangle - \langle v\rangle^2}{\langle v\rangle^2} \Big/ \frac{2}{3A} = \frac{\langle E^2\rangle - \langle E\rangle^2}{\langle E\rangle^2} \Big/ \frac{8}{3A}.$$

The two quantities differ by no more than 5% above 100 keV and by less than 1% below 100 keV. So far, we have not obtained analytical verification of the result.

[13] T. J. WILLIAMSON, *Nucl. Sci. Eng.*, **39**, 273 (1970).

APPENDIX C

GLOSSARY OF FORTRAN VARIABLES USED IN MOD-5

Notes:

1. Numbers in parenthesis reference equations and Figures in the paper by Williamson and Albrecht (Appendix A).

2. If a variable does not appear in the common block the subroutine in which it does appear is given.

3. Jargon:

    a) Group - A broad energy group as defined by cross section sets such as ABN
    b) State - A fine "group" whose cross sections are typically drawn from the broad group set in which it lies.
    c) Operating Iteration - The process of multiplying the state vector into the one step transition matrix which is thus called the "operating matrix (array)"
    d) Generating Matrix - The matrix, typically defined for a very short time step, from which the operating matrix is derived by a sequence of squaring operations.
    e) Real Matrix - The matrix of transition probabilities stored in core
    f) Virtual Matrix - The actual matrix of transition probabilities this may be substantially larger than the Real Matrix but is not stored in core. For an explanation of the relationships between real and virtual matrices see the paper "Calculations of Neutron Time-Energy Distributions ..."

4. * Denotes variables which may be listed at input but for which default parameters have been defined in READ

5. ** Denotes variables which must be defined by the input data set and for which no meaningful default values are assigned.

6. *** Variables which must be updated if dimensions in the COMMON block are changed.

ACCUM	Total population outside real array
ALAM(k)	$N_{s,k}$ (Eq. A12)
ALP(k)	α'_k (Eq. 42)
ALPHA(k)	α_k
AMASS(k)**	A_k, atomic mass of isotope k
AMOM(i,j)	NMOM(i)-th time moment of distribution
AMU(i,m)*	Mean cosine of scattering angle for isotope m in state i (DEFAULT 0.0)
AMUB(k,m)	Group average cosine, group k, isotope m
ANUNOR(i)	Average neutron yield of fissions in state i
ATOM(2m-1,2m)	Name of isotope m
BGF(k)	Steady state fundamental mode flux in group k
BGSF(k)	Steady state leakage flux in group k
BUCKLE*	Buckling, B^2 (DEFAULT 0.0)
CAPT(n)	Neutron capture rate at time n
CCENER	Average fundamental mode energy in steady state
CONVC*	Convergence criteria for iterative calculation of optimized state widths in STAWID (DEFAULT 0.00001)
CORMOM(i,j)	NMOM(i)-th time moment corrected by extrapolation
CRIT*	Row generating criteria (45) (DEFAULT 0.001)
CSENER	Average energy of leakage spectrum neutrons
DB2(i)	Leakage cross section, DB^2, in state i
D32B(k)	Leakage cross section in group k

DDT	Generating time δt (46)
DE(i)	Energy width of state i, E(i-1) - E(i)
DEABN(k)	Energy width of group k
DENS(n)	Neutron density in state NVM at time n
DINT(n,j)	Interpolated time distribution at time n
DIST(n,j)	Raw time distribution at time n
DT(m)	Stepping time after m-1 squarings of the ones step matrix, $DT(m) = DT(1) \cdot 2^{m-1}$
DTI	Time step for interpolated distributions
DTIM(n)	Time step width at time n
DU(i)**	U(i-1) - U(i), Lethargy width of state i (DEFAULT DU(1)=0.0, DU(N)=1.0 E 06)
DUB(k)	Lethargy width of group k
DV(i)	V(i-1) - V(i), velocity width of state i
E(i)*	Lower energy limit of state i (DEFAULT E(1)=10.5 E 06)
EABN(k)	Lower energy limit of group k
EFFK	k_{eff} with extrapolation correction
EII(i)	$\langle 1/E \rangle_i^{-1}$ (A5, A7)
EMIN(m)	E^{min} for isotope m, redefined for each state
ERR(i,j)	Difference between exact and calculated values of NMOM(i)-th moment of density and slowing down density in state NVM
ESTK	k_{eff} estimated from fission distribution without truncation correction

EXM(i,j)	Exact value of NMOM(i)-th moment of density or slowing down density. Based on predictions of Eriksson (ref. 3) and Kosaly and Nemeth for asymtotic distributions in single isotope systems with constant cross sections.
FISS(n)	Fission rate at time n
FLCOR(i)	Correction factor for flux in state i
FLUX(i)	Neutron flux (fundamental mode) in state i
FVAR1,FVAR2, FVAR3,FVAR4	Free storage, not used in basic program
G(i)	Mean Collision rate per neutron in state i (γ_i in Eq. B6)
H(k,l,m)*	Probability that a neutron scattering from isotope m with initial energy in group k will end up in group l. (DEFAULT 0.0)
I,IA,IB,IC, ID, IE, IG,IH	General purpose indices
LEAK (n)	Leakage rate at time n
IND	n in Eq. 46
IPEAK	State number locating the peak of the neutron distribution
J,JJ	Do loop indices (unused in current version of MOD-5)
JROW	The number of rows in the matrix that have been defined
KROW	Number of the next row to be defined
L(j)**	Logical control variable (Appendix D)
LL	Temporary storage for NT

MAXR***	Maximum number of states in real matrix, including absorbing states (DEFAULT 74)
MAXT***	Maximum number of operating time steps allowed by dimensions in common block. (DEFAULT 400)
MAXV***	Maximum number of states in virtual matrix (including absorbing states)(DEFAULT 204)
N*	Number of energy states in real matrix, index of bottom energy state which is used to absorb all neutrons slowing down below lowest energy of interest (DEFAULT 71)
NC	An internally generated index for the external cross section file being read (READ, GET IT)
ND ***	Number of cross section sets that may be held in common (defined in READ, must be redefined if common block dimensions are changed. Value in existing program is ND=5)
NF*	Number of fissionable isotopes (DEFAULT 0)
NG(j)	Index of group to which state j (virtual index) belongs - if NG(j) = 0 state j straddles the boundary between two groups.
NGR***	Number of broad groups in cross section library (external file) (DEFAULT 26)
NI*	Number of isotopes in problem being executed (DEFAULT 1)
NII	Number of non-hydrogen isotopes (TRAN)
NIT	Number of time steps in interpolated output
NM	Number of active energy states in real matrix, NM = N - 1
NMO*	Number of time moments to be evaluated (DEFAULT 2)
NMOM(j)*	Listing of order of time moments to be evaluated (DEFAULT NMOM(1)=1, NMOM(2)=2)

NNG(k)	Index of lowest energy state lying completely within group k
NO	Index of external data set (cross sections) to be retrieved by GET IT
NOLIST(n)**	Index specifying the position of isotope n in the external data files. If NOLIST(1)=0 in primary data set (cards) the external data files (tape or disc) are not read.
NOMAX	Number of isotopes in external data file (tape or disc). This parameter is defined in READ (ftn) 14) and must be updated if the external data set is expanded or contracted.
NORM(i)	Normalization constant
NP1	N+1, Index of the absorbing state (real matrix) used for captured neutrons
NP2	N+2, Index of the absorbing state (real matrix) used for neutrons that have leaked from the system
NP3	N+3, Index of the absorbing state (real matrix) used for neutrons that have caused fission
NSCAT*	Used in connection with STAWID to define the number of lower energy states spanned by the distribution of scattered neutrons from a given state (Fig. 3) (DEFAULT 1)
NT	Maximum number of time steps allowed for problem in execution (must be ≤ MAXT)
NTIME	Running index of time
NTITLE	Number of words allocated in storage for the problem title block.
NTM	NT - 1
NTOP	The number of virtual states above real state 1,- The true state number of real state i is i + NTOP

NVIR*	Number of energy states in virtual matrix - index of absorbing state for neutrons that have slowed below the energy range of interest (DEFAULT 71)
NVM	NVIR-1
N2N(m)	Yield of (n,2n) reactions in group 1 for isotope m.
OPCRIT*	Operating criteria - ratio of first operating time step to mean collision time at peak of source distribution when the matrix is generated (DEFAULT 0.4)
P(i,j)	Transition probability matrix (10-15) - the lower triangular portion of this array is used for storage of transfer coefficients in transposed form ($P_{i,j}$ in Eq. 15)
POP(i,1),POP(i,2)	Population vectors at times n and n+1 respectively - Defined over the range of the real matrix
PTP(i)*	Population vector for the complete state set (Virtual matrix) - an accounting vector used to keep track of population lost when the real matrix is shifted down the state structure. (DEFAULT 0.0)
R(j)	For some state i, the probability of the occurrence of at least j-1 collisions before a neutron leaves the state, $r_{i,j}$ (24)
RHO(m)**	Mass density of isotope m
RHON(m)	Nuclear density of isotope m times 10^{-24}
RI(j)	Resonance self shielding correction factors, 1-fission, 2-capture, 3-total, 4-elastic
RR(i)	Average number of collisions before a neutron leaves state i (24)

RSD(j)	Relative standard deviation of time distributions (58)
RSDX(j)	Relative standard deviation of time distributions calculated from asymptotic formulae
RSDR(j)	Percent difference of computed relative standard deviation with respect to asymptotic value
RSS(i,j,l,m)*	Resonance self shielding coefficients (ABN) (DEFAULT 1.0) i = group index j = index defining value of σ_o 1 - 0 barns 2 - 1 barn 3 - 10 barns 4 - 100 barns 5 - 1000 barns 6 - ≥ 10000 barns l = index specifying cross section type 1 - fission 2 - capture 3 - total 4 - elastic m = isotope index
SARG(n)	Resonance self shielding parameter $\sigma_{t,n}$ on page 44 of ABN (Ref. 6)
SCALE(k,m)*	Scale factor for isotope m in group k (21,26) (DEFAULT 1.0)
SCRIT*	Criteria for determining the fraction of an existing neutron distribution that is bypassed when the real matrix is shifted downward in energy (DEFAULT 0.001)
SDENS(n)	Slowing down density at time n and energy E(NVM)
SFLUX(i)	Steady state leakage flux in state i
SIGC(i,m) SIGE(i,m) SIGF(i,m)	

SIGN(i,m)	Capture, elastic scattering, fission, and inelastic scattering cross sections for isotope m in state i (divided by SIGT(i) after XSECT)
SIGT(i),SIGTR(i)	Total and transport cross sections in state i
SIGCB(k,m)** SIGEB(k,m) SIGFB(k,m) SIGNB(k,m) SIGTB(k,m)	Capture, elastic scattering, fission, inelastic scattering and total cross sections for isotope m in group k
SIGEP(m)	First factor on right side of Eq. 36 - for isotope m
SIGTBT(k) SIGTRB(k)	Total and transport cross sections in group k
SQCRIT*	Matrix squaring criteria (DEFAULT 0.2)
SSTAR(n)	Resonance self shielding parameter $\sigma_{t,n}$* on page 44 of ABN
SUMPOP	Total fraction of the population that has been bypassed by the real matrix as it moves down in energy
SZERO(l)	Resonance self shielding parameter $\sigma_{o,\ell}$ on page 42 of ABN
TIM(n)*	Time at time step n (DEFAULT TIM(1)=0.0)
TIMD(n)	$\frac{1}{2}$(TIM(n) + TIM(n+1))
TIMWID*	Width of source pulse in time (DEFAULT 0.0)
TITLE(k)**	Title block storage
TOTL(n)	Total neutron loss rate at time n
U(i)*	Upper lethargy boundary for state i (DEFAULT U(1)=0.0)

V(i)	Lower velocity boundary for state i
VII(i)	Inverse of expectation on inverse scattering velocity (as used in calculation of B6)
ZA,ZB,ZC,ZD,ZE	Free parameters

APPENDIX D

LOGICAL CONTROL VARIABLES

Note: The integer variable L provides 30 locations for variables which control the sequence of operations performed by MOD-5. L(1) through L(20) are reserved for the operations listed below. L(21) through L(30) remain unassigned and are available for the programmer's use. In general, if L(n) = 1 the operation listed is carried out and if L(n) = 0 the operation is not carried out. Note that L(2) must always be defined to be 1 in the problem data set and this fact is used in READ (ftn 81,82) as a simple consistency check on the punched cards.

n	IF(L(n).EQ.1)
1	Set up run only, execution terminates after GENTIM
2	Problem initialization variable.
3	The real array is at the bottom of the virtual array. L(3) = 1 initially if the real and virtual arrays have the same dimension, i.e., if N = NVIR.
4	Define the state structure from E(NVM) upward. Default (0) value assumes state structure is to be defined from E(1) downward.
5	On-line plot of distributions in lethargy at time determined in AMULT.
6	Call STAWID to optimize state structure.
7	Call EXACT to calculate and print asymptotic time moments.
8	The source distribution in energy and the value of TIM(1) are specified in the input data set. If TIM(1) is not specified a default value of 0.0 seconds is assumed.
9	The source is to be monoenergetic (located in state 2) and uniformly distributed in time for an interval given by the input value of TIMWID.
10	There is fissionable material in the system
11	The source has a delta function distribution in time and energy. All neutrons start in state 1.
12	Inelastic scattering occurs. This variable must have an input value of 0. If one or more rows of the variable H has non-zero elements the program redefines L(12) = 1.
13	IF(L(5).EQ.1) plot distributions in lethargy as with L(5) = 1 but at closer intervals as defined in AMULT.
14	Punch output
15	Print DENS and SDENS

n	IF(L(n).EQ.1)
16	Print FISS, LEAK, CAPT, and TOTL
17	Print LEAK, CAPT, TOTL, DENS and SDENS
18	Write out detailed distributions (Interpolated distributions are always written)
19	Disregard instructions to terminate on ROWSUM error (WRITE2). XSECT defines L(19) = 1 when (n,2n) reactions take place.
20	Internally generated call for MODPLOT
21-30	Unassigned

APPENDIX E

DESCRIPTIONS OF SUBROUTINE FUNCTIONS

The MOD-5 package consists of a control program, MAIN, and 20 subroutines. MAIN is discussed in detail in Section I of this document. The subroutines are briefly described below, Equations referenced are to be found in the paper in APPENDIX A.

AMULT
1) Multiplies state vector into the transition matrix
2) Evaluates fission, capture, leakage and total loss rate at time NT; and density and slowing down density in bottom energy group.
3) Determines whether the lethargy dependent neutron density should be printed (punched). This is done if the current time step straddles a time $1x10^{-n}$, $2x10^{-n}$ or $5x10^{-n}$ seconds where n is an integer. If L(13) = 1 the density in lethargy is also printed at times near 1.5, 3, and $7x10^{-n}$ seconds.

EXACT
(OPTIONAL ROUTINE) Calculates asymptotic values of positive or negative moments of DENS to any order using expressions quoted in Williams, The Slowing Down and Thermalization of Neutrons, Chapter IX, Section II. First and second positive moments of SDENS are calculated using results of Pal and Nemeth, Nukleonik, 1, 5, 165 (1959).

GENRAT
Generates new rows of the transition matrix using Eqs. 14 and 15, after testing to see which rows satisfy Eq. 44 for the time step in use.

GENTIM
1) Determines the operating time step width from the values of OPCRIT and the state decay constant at the state with the greatest population.
2) Determines generating time and parameters each time a new real transition probability array is generated. See Eqs. 44-46.

GETIT
Called from READ to retrieve isotope numbers, names and masses, and the cross section set, from external files. Data sets are read sequentially and discarded until the desired set is found.

INCOND	1) Computes the average fission yield of neutrons in each state using fission yield parameters in Abagayan, et al. 2) Defines the source vector if it is to be a delta function or a fission spectrum. 3) Normalizes the source spectrum.
INTERP	Computes linearly interpolated values of time distributions (fission rate, etc.) on a uniform time mesh of up to 200 points. The first 20 points are spaced at $\frac{1}{4}$ the separation of the remaining points.
LIBRAR	This routine is intended for use with the ABN 26 group cross section library. 26 group microscopic cross sections are corrected for resonance self-shielding and converted to macroscopic cross sections. These are then used to define cross sections for each state with energy interval weighted averages for those states lying on a group boundary. The resonance self shielding coefficients are interpolated linearly if $\sigma_o < 1$ and logarithmically if $\sigma_o > 1$.
MODPLT	(OPTIONAL ROUTINE) Provides for on-line plotting of the lethargy dependent neutron density with no correction for non-uniformity of state widths.
MOMENT	1) Computes up to 21 moments of time distributions. 2) Computes exponential extrapolation corrections to the time distributions. 3) Computes multiplication constant. 4) Computes first energy moment of steady state core and leakage fluxes.
NORMAL	Normalizes time dependent distributions and fluxes to unit integral over time or lethargy.
OUTPUT	1) Computes relative standard deviation of time distributions. 2) Computes 26 group flux. 3) Prints or punches final output data.
PARAM	1) Defines lethargy, energy, and velocity values for state boundaries; and lethargy, energy and velocity widths of each state. May start from pre-determined lethargies of state boundaries or lethargy widths of states.

2) Evaluates NG(i) to define group to which state i belongs.
3) Evaluates NNG(k) to specify index of lowest energy state lying completely in group k.

READ

1) Initializes parameters ND, NOMAX, MAXT, MAXR, MAXV, NGR, and NTITLE which specify dimensionality of the common block and the number of isotopes in the external file.
2) Assigns DEFAULT values.
3) Re-orders isotopes in ascending mass order (Exception: when present, hydrogen is always listed last by READ).
4) Reads all card input data.
5) Provides parameter and vector initial values.

SQUARE

Squares the transition matrix. Elements of the newly squared matrix are stored in their transposed position (lower triangular) in the matrix until the squaring process has been completed. The elements are then transposed to their normal position. SQUARE provides two squaring routines, one for a matrix in which not all of the rows have been defined, and one for a fully defined matrix.

STAWID

(OPTIONAL ROUTINE) This routine is used to adjust the lethargy width of the states to obtain optimal treatment of elastic scattering. (see Appendix A, pp. 45-46). To employ this routine the user must define NSCAT, the number of lower energy states into which neutrons are allowed to scatter from a given state. STAWID automatically calculates an initial estimate of the desired lethargy width and then iterates on this to refine the value.

TRAN

This routine computes the transfer coefficient matrix (transition probabilities are assembled from these in GENRAT). The model assumes constant cross sections across each state. The transfer coefficient array is computed in transposed form so it may be stored in the lower triangular portion of the matrix P(i,j). Transition probabilities are stored in the upper triangular and diagonal elements of the array. Inter-state inelastic scattering transfer probabilities are derived from the inelastic transfer matrices of the 26 group cross section set using energy interval weighting.

WRITE1

Lists input and computed data for problem description. If common block is altered such that ND (maximum number of isotopes in system) exceeds 5 this subroutine will have to be updated.

WRITE2	Lists state structure parameters and tests the transfer coefficient array to see that probabilities along a row (column in transposed form) sum to unity.
XSECT	1) Macroscopic cross sections are divided by the total cross section to normalize them for use in defining transfer coefficients. 2) The inelastic scattering array is tested for (n,2n) reactions. 3) The inelastic scattering array is normalized.

APPENDIX F

MOD-5 Listing

```
C***                                  *********                                5
C***                                  * MOD-5 *                               10
C***                                  *********                               15
C***                                                                          20
C***                                                                          25
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G(      30
     1171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)     35
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SCENS(4      40
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(      45
     4201),DE(201),VTI(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2      50
     5(204),FVAR3(204),FVAR4(204)                                             55
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2      60
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(2,2),EXM(21       65
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),      70
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI      75
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI      80
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDR      85
     6(2),RSDX(2)                                                             90
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,I      95
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N     100
     2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT     105
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE           110
      REAL LEAK,NORM                                                          115
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6      120
     1)                                                                       125
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT)      130
     1, (FISS,DIST)                                                           135
C***                                                                          140
C***                                                                          145
C***  MOD-5 IS A ONE DIMENSIONAL SLOWING DOWN CODE WRITTEN EXCLUSIVELY        150
C***  IN FORTRAN IV.  NEUTRON MODERATION AND REGENERATION ARE TREATED         155
C***  AS DISCRETE-TIME, DISCRETE-STATE MARKOV PROCESSES.  THE PHYSICAL        160
C***  BASIS FOR ALGORITHMS USED IN THIS CODE MAY BE FOUND IN A PAPER BY       165
C***  WILLIAMSON AND ALBRECHT IN NUCLEAR SCIENCE AND ENGINEERING, VOL.        170
C***  37, PAGES 41-58 (1969).                                                 175
C***  IN GENERAL, COMMENT STATEMENTS REFER TO OPERATIONS CARRIED OUT IN       180
C***  THE STATEMENTS IMMEDIATELY FOLLOWING.  EQUATION AND TABLE NUMBERS       185
C***  ARE FROM THE REFERENCE DESCRIBED ABOVE.                                 190
C***                                                                          195
C***  SUBROUTINE CANCEL(2) CANCELS UNDERFLOWS.                                200
      CALL CANCEL (2)                                                         205
    1 CONTINUE                                                                210
      CALL READ (&24)                                                         215
      IF (L(6).EQ.1) CALL STAWID (&1)                                         220
      CALL PARAM                                                              225
C***  THE NEXT 7 STATEMENTS ARE EXECUTED WHEN INITIALLY DEFINING TRANS-       230
C***  ITION PROBILITIES AND WHENEVER THE REAL (OPERATING) MATRIX IS           235
C***  CHANGED IN SIZE OR RELOCATED ON THE VIRTUAL ARRAY.                      240
    2 CALL LIBRAR                                                             245
      IF (L(2).EQ.1) CALL WRITE1                                              250
      CALL XSECT                                                              255
      CALL TRAN                                                               260
      CALL WRITE2 (&1)                                                        265
      IF (L(2).EQ.1.OR.L(10).EQ.1) CALL INCOND                                270
      CALL GENTIM                                                             275
C***  EXECUTION TERMINATES HERE IF L(1)=1. (SET-UP ONLY)                      280
      IF (L(1).EQ.1) GO TO 1                                                  285
C***  THE NEXT 7 STATEMENTS GENERATE THE TRANSITION MATRIX.                   290
      IX=IND+1                                                                295
      DO 4 I=1,IX                                                             300
      IF (KROW.GE.N) GO TO 3                                                  305
      CALL GENRAT                                                             310
    3 IF (I.LE.IND) CALL SQUARE                                               315
      IF (I.EQ.IX.AND.KROW.LE.NM) CALL GENRAT                                 320
    4 CONTINUE                                                                325
      ZA=DT(NTIME)                                                            330
C***  THE VECTOR FLCOR (BELOW) PROVIDES FACTORS FOR CORRECTING CALCULA-       335
C***  TIONS OF FLUX FOR EFFECTS OF VARIABLE TIME STEP WIDTH.  USED IN         340
C***  SUBROUTINE AMULT.                                                       345
      DO 5 IA=2,NM                                                            350
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      5 FLUX(IA)=(1.-EXP(-G(IA)*ZA))/G(IA)                                    355
        DO 6 IA=1,NM                                                          360
      6 POP(IA,2)=PTP(IA+NTOP)                                                365
        POP(NP1,2)=PTP(NVIR+1)                                                370
        POP(NP2,2)=PTP(NVIR+2)                                                375
        POP(NP3,2)=PTP(NVIR+3)                                                380
C***    POP(N,2) REPRESENTS ONLY THE ACCUMULATION OF NEUTRONS SLOWING         385
C***    DOWN BELOW THE LOWER BOUNDARY OF THE CURRENT REAL ARRAY.              390
        POP(N,2)=0.                                                           395
C***    THE MAIN OPERATING LOOP (AN IMPLIED DO LOOP) BEGINS HERE.             400
      7 CONTINUE                                                              405
        NT=NT+1                                                               410
        IF (L(9).EQ.0) GO TO 8                                                415
C***    THE NEXT 4 STATEMENTS ARE EXECUTED WHEN THE SOURCE IS A PULSE OF      420
C***    FINITE LENGTH.  THIS PROGRAM AUTOMATICALLY GENERATES A SOURCE OF      425
C***    DURATION=TIMWID AND DELTA FUNCTION SPECTRUM IN STATE 2 WHEN L(9)=1    430
        IF (TIM(NT).LT.TIMWID) POP(2,2)=POP(2,2)+DT(NTIME)/TIMWID             435
        IF (TIM(NT).LT.TIMWID) GO TO 8                                        440
        POP(2,2)=POP(2,2)-(TIM(NT)+DT(NTIME)-TIMWID)/TIMWID                   445
        L(9)=0                                                                450
      8 CONTINUE                                                              455
        CALL AMULT                                                            460
        IF (L(5).EQ.1.AND.L(20).EQ.1) CALL MODPLT                             465
        L(20)=0                                                               470
C***    IF THE MAXIMUM NUMBER OF TIME STEPS (MAXT) HAS BEEN REACHED           475
C***    CONTROL IS PASSED TO FINAL DATA MANIPULATION AND OUTPUT ROUTINES.     480
        IF (NT.EQ.MAXT) GO TO 16                                              485
C***    THE TOTAL POPULATION OUTSIDE THE REAL ARRAY IS DETERMINED.  IF        490
C***    THIS EXCEEDS 99 PERCENT, CONTROL PASSES TO OUTPUT ROUTINES.           495
        ACCUM=SUMPOP+POP(N,2)+POP(NP1,2)+POP(NP2,2)+POP(NP3,2)+PTP(NVIR)      500
        ZX=ACCUM                                                              505
        IF (ACCUM.GT..99.AND.DENS(NT).LT..00001) GO TO 16                     510
C***    IF THE REAL ARRAY LIES AT THE BOTTOM OF THE VIRTUAL ARRAY             515
C***    EXECUTION CONTINUES WITHOUT FURTHER TESTING.                          520
        IF (L(3).EQ.1) GO TO 13                                               525
C***    THE FRACTION OF THE POPULATION OF THE REAL ARRAY THAT HAS SLOWED      530
C***    BELOW ITS LOWER ENERGY LIMIT IS EVALUATED.  IF ZB EXCEEDS 0.1         535
C***    PERCENT A NEW REAL ARRAY WILL BE DEFINED.  OTHERWISE THE NORMAL       540
C***    CONTROL SEQUENCE CONTINUES.                                           545
        ZB=POP(N,2)/(1.-ACCUM)                                                550
        IF (ZB.LT.SCRIT) GO TO 13                                             555
C***    THE NEXT ELEVEN STATEMENTS DETERMINE THE NEW POSITION OF THE REAL     560
C***    ARRAY BY FINDING THE (VIRTUAL) STATE NUMBER SUCH THAT 0.1 PERCENT     565
C***    OF THE EXISTING POPULATION WILL BE BYPASSED BY THE NEW ARRAY.         570
        IB=0                                                                  575
        ZC=0.                                                                 580
        ZB=1.-ACCUM                                                           585
        DO 9 IA=2,N                                                           590
        ZC=ZC+POP(IA,2)                                                       595
        ZD=ZC/ZB                                                              600
        IF (ZD.LT.SCRIT) GO TO 9                                              605
        IB=IA                                                                 610
        GO TO 10                                                              615
      9 CONTINUE                                                              620
     10 IA=NTOP                                                               625
C***    NTOP IS THE NUMBER OF VIRTUAL STATES ABOVE THE REAL STATES.           630
C***    THUS REAL STATE NUMBER 1 IS VIRTUAL STATE NUMBER NTOP+1.              635
C***    WHEN THE FIRST STATES OF REAL AND VIRTUAL MATRICIES ARE COINCIDENT     640
C***    DEFINE NTOP = 0.                                                      645
        NTOP=NTOP+IB                                                          650
C***    THE VECTOR PTP IS UPDATED                                             655
        DO 11 IA=1,NM                                                         660
     11 PTP(IA+IB)=POP(IA,2)                                                  665
        PTP(NVIR)=PTP(NVIR)+POP(N,2)                                          670
        PTP(NVIR+1)=POP(NP1,2)                                                675
        PTP(NVIR+2)=POP(NP2,2)                                                680
        PTP(NVIR+3)=POP(NP3,2)                                                685
        SUMPOP=SUMPOP+ZC                                                      690
C***    IF THE LOWEST STATE OF THE NEW REAL ARRAY LIES BELOW THE LOWEST       695
C***    STATE OF THE VIRTUAL ARRAY, THE REAL ARRAY IS REDUCED IN SIZE AND     700
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C***  THE CONTROL VARIABLE L(3) IS SET EQUAL TO 1.                    705
      IB=NVIR-NTOP                                                    710
      IF (IB.GT.N) GO TO 12                                           715
      WRITE (6,19) NT,N,IB                                            720
      N=IB                                                            725
      NP1=N+1                                                         730
      NP2=N+2                                                         735
      NP3=N+3                                                         740
      NM=N-1                                                          745
      L(3)=1                                                          750
      LL=NT                                                           755
   12 CONTINUE                                                        760
      L(2)=0                                                          765
C***  CONTROL RETURNS TO ARRAY GENERATING ROUTINE.                    770
      GO TO 2                                                         775
   13 CONTINUE                                                        780
C***  THE NEXT SEVEN STATEMENTS LOCATE THE FIRST MAXIMUM IN THE NEUTRON 785
C***  DISTRIBUTION.                                                   790
      IB=IPEAK-NTOP                                                   795
      ZE=POP(IB,2)                                                    800
      DO 14 IA=IB,NM                                                  805
      IF (POP(IA,2).LT.ZE) GO TO 14                                   810
      ZE=POP(IA,2)                                                    815
      IPEAK=IA+NTOP                                                   820
   14 CONTINUE                                                        825
C***  THE DECAY CONSTANT FOR THE FIRST MAXIMUM IS CALCULATED          830
      ZA=G(IPEAK-NTOP)*DT(NTIME)                                      835
      WRITE (6,20) NT,NTIME,IPEAK,ZA,ZX                               840
C***  IF THE DECAY CONSTANT EXCEEDS THE MATRIX SQUARING CRITERION GO  845
C***  BACK TO THE BEGINNING OF THE OPERATIONAL LOOP.                  850
      IF (ZA.GT.SQCRIT) GO TO 7                                       855
C***  IF NOT, EXECUTE THE NEXT NINE STATEMENTS TO UPDATE THE FLUX     860
C***  CORRECTION VECTOR, SQUARE THE MATRIX, AND GENERATE NEW ROWS AS  865
C***  NECESSARY.                                                      870
      ZA=DT(NTIME)*2.                                                 875
      DO 15 IA=2,NM                                                   880
   15 FLCOR(IA)=(1.-EXP(-G(IA)*ZA))/G(IA)                             885
      CALL SQUARE                                                     890
      NTIME=NTIME+1                                                   895
      DT(NTIME)=DT(NTIME-1)*2.                                        900
      I=1                                                             905
      DDT=DT(NTIME)                                                   910
      IF (JROW.LT.NM) CALL GENRAT                                     915
      WRITE (6,21) NT,IPEAK,DT(NTIME)                                 920
C***  GO BACK TO BEGINNING OF OPERATING LOOP.                         925
      GO TO 7                                                         930
   16 NTM=NT-1                                                        935
      DO 17 IA=2,NVM                                                  940
      FLUX(IA)=FLUX(IA)*RR(IA)                                        945
   17 SFLUX(IA)=SFLUX(IA)*RR(IA)                                      950
C***  UPDATE PTP                                                      955
      DO 18 IA=1,NM                                                   960
   18 PTP(IA+NTOP)=POP(IA,2)                                          965
      PTP(NVIR)=PTP(NVIR)+POP(N,2)                                    970
      PTP(NVIR+1)=POP(NP1,2)                                          975
      PTP(NVIR+2)=POP(NP2,2)                                          980
      PTP(NVIR+3)=POP(NP3,2)                                          985
C***  THE NEXT FIVE SUBROUTINES CALLED PERFORM FINAL MANIPULATIONS AND 990
C***  WRITE OUT DATA.                                                 995
      CALL NORMAL                                                    1000
      CALL MOMENT                                                    1005
      CALL INTERP                                                    1010
      IF (L(7).EQ.1) CALL EXACT                                      1015
      CALL OUTPUT                                                    1020
      WRITE (6,22) (TITLE(I),I=1,18)                                 1025
      WRITE (6,23)                                                   1030
      GO TO 1                                                        1035
C***  EXECUTION TERMINATES WHEN THE INPUT DATA LIST HAS BEEN EXHAUSTED 1040
C***  OR WHEN AN ERROR CONDITION EXISTS IN THE DATA SET.              1045
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C***                                                                    1060
   19 FORMAT ('0',//////,'***AT OPERATING ITERATION',I4,' THE ARRAY SIZE  1065
     1 HAS BEEN REDUCED FROM',I4,' TO',I4,'.****',//////)               1070
   20 FORMAT (' NT=',I3,'  NTIME=',I2,'  IPEAK=',I3,'  ZA=',E10.3,'  ZX=  1075
     1',E10.3)                                                          1080
   21 FORMAT ('0',////////,'----- AT OPERATING ITERATION NUMBER',I4,' TH  1085
     1E ARRAY HAS BEEN SQUARED',/,' THE PULSE PEAK IS LOCATED IN VIRTUAL  1090
     2 STATE',I4,', AND THE NEW TIME STEP IS',1PE10.3,'.')              1095
   22 FORMAT ('0',///,18A4,//,' **** END **** END **** END **** END ****  1100
     1 END ****')                                                       1105
   23 FORMAT ('1')                                                      1110
   24 CONTINUE                                                          1115
      END                                                               1120
```

**** INCOND ****

```
      SUBROUTINE INCOND                                                 A    5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),GI  A   10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)  A   15
     2,CB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SDENS(4  A   20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(  A   25
     42201),DE(201),EII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2  A   30
     5(204),FVAR3(204),FVAR4(204)                                       A   35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2  A   40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21  A   45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),  A   50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI  A   55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI  A   60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDR  A   65
     6(2),RSDX(2)                                                       A   70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,I  A   75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N  A   80
     2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTIILE,NTM,NT  A   85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE       A   90
      REAL LEAK,NORM                                                    A   95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6  A  100
     1)                                                                 A  105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT)  A  110
     1, (FISS,DIST)                                                     A  115
C***                                                                    A  120
C***  AMULT (1) MULTIPLIES STATE VECTOR INTO TRANSITION PROBABILITY     A  125
C***  MATRIX TO YIELD NEW STATE VECTOR, REF. EQ. 9, (2) DEFINES TIME,   A  130
C***  (3) PRINTS POPULATION VECTOR AND ITS MOMENTS AT PRESELECTED TIMES.  A  135
C***                                                                    A  140
C***  INITIALIZE THE VECTORS                                            A  145
      DO 1 IA=1,NP3                                                     A  150
      POP(IA,1)=POP(IA,2)                                               A  155
    1 POP(IA,2)=0.                                                      A  160
C***  MULTIPLY VECTOR INTO MATRIX.                                      A  165
      DO 2 IA=1,JROW                                                    A  170
      DO 2 IB=1,IA                                                      A  175
    2 POP(IA,2)=POP(IA,2)+POP(IB,1)*P(IB,IA)                            A  180
      DO 3 IA=KROW,NP3                                                  A  185
      POP(IA,2)=POP(IA,1)                                               A  190
      DO 3 IB=1,JROW                                                    A  195
    3 POP(IA,2)=POP(IA,2)+POP(IB,1)*P(IB,IA)                            A  200
C***  AT THIS POINT POP(IA,1) IS DEFINED FOR TIM(NT) AND POP(IA,2) FOR  A  205
C***  TIM(NT+1)                                                         A  210
      FISS(NT)=0.                                                       A  215
      IF (L(10).EQ.0) GO TO 5                                           A  220
C***  NT IS THE TOTAL ELAPSED NUMBER OF OPERATING TIME STEPS.           A  225
C***  FISS(NT) IS WEIGHTED BY FISSION NEUTRON YIELD.  THE FISSION TERM  A  230
C***  IN TOTL(NT) IS NOT SO WEIGHTED.                                   A  235
C***  THE FUNCTIONS FISS(NT) ,CAPT(NT),LEAK(NT),SDENS(NT), AND TOTL(NT)  A  240
C***  ARE DEFINED AS THE NUMBER OF EVENTS ON THE INTERVAL  TIM(NT+1) -  A  245
C***  TIM(NT).  DENS(NT) IS DEFINED AT TIM(NT)                          A  250
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```
      DO 4 IA=1,NM                                                          A  255
    4 FISS(NT)=FISS(NT)+POP(IA,1)*P(IA,NP3)*ANUNOR(IA)                      A  260
    5 CONTINUE                                                              A  265
      CAPT(NT)=POP(NP1,2)-POP(NP1,1)                                        A  270
      LEAK(NT)=POP(NP2,2)-POP(NP2,1)                                        A  275
      TOTL(NT)=LEAK(NT)+CAPT(NT)+POP(NP3,2)-POP(NP3,1)                      A  280
      DENS(NT)=POP(NM,1)                                                    A  285
C***  THE FUNCTION SDENS(NT) IS VALID AFTER TIME STEP LL, WHEN THE REAL     A  290
C***  MATRIX REACHES THE BOTTOM OF THE VIRTUAL MATRIX.                      A  295
      SDENS(NT)=POP(N,2)-POP(N,1)                                           A  300
      TIM(NT+1)=TIM(NT)+DT(NTIME)                                           A  305
      DELT=DT(NTIME)/DT(1)                                                  A  310
      DO 6 IA=2,NM                                                          A  315
      IB=IA+NTOP                                                            A  320
      ZA=POP(IA,1)*FLCOR(IA)                                                A  325
      SFLUX(IB)=SFLUX(IB)+ZA*P(IA,NP2)                                      A  330
    6 FLUX(IB)=FLUX(IB)+ZA                                                  A  335
      IF (NT.EQ.1) GO TO 7                                                  A  340
C***  TEST TO SEE IF POPULATION VECTOR SHOULD BE PRINTED.                   A  345
      ZA=ALOG10(TIM(NT)-TIM(1))                                             A  350
      ZB=AINT(ZA)                                                           A  355
      ZA=ZA-ZB+1.                                                           A  360
      ZB=ALOG10(TIM(NT)+DT(NTIME)-TIM(1))                                   A  365
      ZC=AINT(ZB)                                                           A  370
      ZB=ZB-ZC+1.                                                           A  375
      IF (ZB.LT.ZA) ZB=ZB+1.                                                A  380
      IF (ZA.LE.1..AND.ZB.GT.1.) GO TO 7                                    A  385
      IF (ZA.LE..69897.AND.ZB.GT..69897) GO TO 7                            A  390
      IF (ZA.LE..30103.AND.ZB.GT..30103) GO TO 7                            A  395
      IF (L(13).EQ.0) GO TO 12                                              A  400
      IF (ZA.LE..17609.AND.ZB.GT..17609) GO TO 7                            A  405
      IF (ZA.LE..47712.AND.ZB.GT..47712) GO TO 7                            A  410
      IF (ZA.LE..84510.AND.ZB.GT..84510) GO TO 7                            A  415
      GO TO 12                                                              A  420
    7 CONTINUE                                                              A  425
      L(20)=1                                                               A  430
C***  CONVERT POPULATION TO DENSITY IN LETHARGY AND WRITE DENSITY VECTOR     A  435
      DO 8 IA=2,NM                                                          A  440
    8 POP(IA,1)=POP(IA,1)/DU(IA+NTOP)                                       A  445
      ID=NTOP+1                                                             A  450
      ZA=TIM(NT)-TIM(1)                                                     A  455
      WRITE (6,17) NT,TIM(1),ZA,ID                                          A  460
      IC=10*((NTOP-1)/10)+11                                                A  465
      ID=NTOP+1                                                             A  470
      IE=IC-ID                                                              A  475
      WRITE (6,14) (ID,(POP(IA,1),IA=1,IE))                                 A  480
      IC=((NM+NTOP)/10)*10+1                                                A  485
      IG=(IE-IC)/10                                                         A  490
      DO 9 IB=1,IG                                                          A  495
      IE=IC+9-NTOP                                                          A  500
      IH=IC-NTOP                                                            A  505
      WRITE (6,14) (IC,(POP(IA,1),IA=IH,IE))                                A  510
    9 IC=IC+10                                                              A  515
      IC=IC-NTOP                                                            A  520
      WRITE (6,14) (IC,(POP(IA,1),IA=ID,NM))                                A  525
      WRITE (6,13) (POP(IA,1),IA=N,NP3)                                     A  530
C***  CONVERT DENSITY BACK TO POPULATION                                    A  535
      DO 10 IA=2,NM                                                         A  540
   10 POP(IA,1)=POP(IA,1)*DU(IA+NTOP)                                       A  545
C***  COMPUTE ENERGY AND VELOCITY MOMENTS OF THE POPULATION VECTOR.         A  550
      ZA=0.                                                                 A  555
      ZB=0.                                                                 A  560
      ZC=0.                                                                 A  565
      ZD=0.                                                                 A  570
      ZE=0.                                                                 A  575
      DO 11 IA=1,NM                                                         A  580
      IAP=IA+NTOP                                                           A  585
      ZA=ZA+POP(IA,1)                                                       A  590
      ZB=ZB+POP(IA,1)*EII(IAP)                                              A  595
      ZC=ZC+POP(IA,1)*EII(IAP)*EII(IAP)                                     A  600
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   11 ZE=ZE+POP(IA,1)*VII(IAP)*VII(IAP)                                  A  610
      DEV=0.                                                             A  615
      VDEV=0.                                                            A  620
      EBAR=ZB/ZA                                                         A  625
      EBAR2=SQRT(ZC/ZA)                                                  A  630
      ZB=(ZC*ZA)/(ZB*ZB)-1.                                              A  635
      IF (ZB.GT.0.) DEV=SQRT(ZB)                                         A  640
      VBAR=ZD/ZA                                                         A  645
      VBAR2=SQRT(ZE/ZA)                                                  A  650
      ZC=(ZE*ZA)/(ZD*ZD)-1.                                              A  655
      IF (ZD.GT.0.) VDEV=SQRT(ZD)                                        A  660
      WRITE (6,18) EBAR,VBAR,EBAR2,VBAR2,DEV,VDEV                        A  665
      IF (L(14).EQ.0) GO TO 12                                           A  670
      WRITE (7,15) TIM(NT),NT,NTOP                                       A  675
      WRITE (7,16) (POP(IA,1),IA=1,NM)                                   A  680
   12 CONTINUE                                                           A  685
      RETURN                                                             A  690
C***                                                                     A  695
C***                                                                     A  700
   13 FORMAT ('0','   ABSORBING STATE POPULATIONS',5X,1P4E10.3)          A  705
   14 FORMAT (I4,1PE13.3,1P4E10.3,5X,1P5E10.3)                           A  710
   15 FORMAT ('     TIME =',E10.3,'   NT=',I4,' NTOP=',I4)               A  715
   16 FORMAT (8E10.3)                                                    A  720
   17 FORMAT ('0',///,' ---AT OPERATING ITERATION NO.',I4,' AND TIME =', A  725
     1E10.3,' +',E10.3,' SECONDS,',/,'    THE NEUTRON DENSITY (LETHARGY)  A  730
     2 VECTOR IS WRITTEN BEGINNING WITH VIRTUAL STATE',I4,'.',//)        A  735
   18 FORMAT ('0',/,10X,'MEAN ENERGY (DENSITY AVERAGED) =',1PE11.4,5X,'M A  740
     1EAN VELOCITY                =',1PE11.4,/,10X,'R. M. S. ENERGY     A  745
     2          =',1PE11.4,5X,'R. M. S. VELOCITY          =',1PE11.4,/,  A  750
     310X,'RELATIVE STANDARD DEVIATION    =',1PE11.4,5X,'RELATIVE STANDA A  755
     4RD DEVIATION =',1PE11.4,///)                                       A  760
      END                                                                A  765
```


**** EXACT ****

```
      SUBROUTINE EXACT                                                   B    5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G( B   10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5) B   15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SDENS(4 B   20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),F( B   25
     4201),DF(201),FII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2 B   30
     5(204),FVAR3(204),FVAR4(204)                                        B   35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2 B   40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21 B   45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5), B   50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI B   55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI B   60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSC(6),RSCR B   65
     6(2),RSDX(2)                                                        B   70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,I B   75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N B   80
     2A,ND,NGR,NE,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT B   85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE       B   90
      REAL LEAK,NORM                                                     B   95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6 B  100
     1)                                                                  B  105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT) B  110
     1, (FISS,DIST)                                                      B  115
C***                                                                     B  120
C***  EXACT IS AN OPTIONAL SUBROUTINE WHICH CALCULATES ASYMPTOTIC VALUES B  125
C***  OF POSITIVE OR NEGATIVE MOMENTS OF DENS TO ANY ORDER USING         B  130
C***  EXPRESSIONS QUOTED IN WILLIAMS, 'THE SLOWING DOWN AND THERMAL-     B  135
C***  IZATION OF NEUTRONS', CHAPTER IX, SECTION 11.  FIRST AND SECOND    B  140
C***  POSITIVE MOMENTS OF SDENS ARE CALCULATED USING RESULTS OF PAL AND  B  145
C***  NEMETH, NUKLEONIK, 1, 5, 165 (1959).                               B  150
C***                                                                     B  155
```

```
      ZA=ALPHA(1)                                                          B  160
      VSIG=VII(NVM)*SIGEB(25,1)                                            B  165
      XI=1.                                                                B  170
      IF (ZA.GT.0.) XI=1.+(ZA*ALOG(ZA))/(1.-ZA)                            B  175
C***  MOMENTS OF DENS                                                      B  180
      DO 4 IA=1,NMO                                                        B  185
      IF (NMOM(IA).LT.0) GO TO 2                                           B  190
C***  POSITIVE MOMENTS                                                     B  195
      ID=NMOM(IA)                                                          B  200
      EXM(IA,2)=(1.E06/VSIG)**NMOM(IA)                                     B  205
      DO 1 IB=1,ID                                                         B  210
      ZB=IB                                                                B  215
    1 EXM(IA,2)=EXM(IA,2)*(ZB/(1.-(2.*(1.-ZA**(1.+ZB/2.)))/((ZB+2.)*(1.-   B  220
     1ZA))))                                                               B  225
      GO TO 4                                                              B  230
C***  NEGATIVE MOMENTS                                                     B  235
    2 EXM(IA,2)=XI*VSIG**.5E-06                                            B  240
      IF (AMASS(1).EQ.1.) GO TO 4                                          B  245
      IF (NMOM(IA).EQ.(-1)) GO TO 4                                        B  250
      ID=-NMOM(IA)-1                                                       B  255
      DO 3 IB=1,ID                                                         B  260
      ZB=IB                                                                B  265
      IF (IB.NE.2) EXM(IA,2)=EXM(IA,2)*(VSIG/1.E06)*(1.-(2.*(1.-ZA**(1.-   B  270
     1ZB/2.)))/((2.-ZB)*(1.-ZA)))/(-ZB)                                    B  275
      IF (IB.EQ.2) EXM(IA,2)=EXM(IA,2)*(VSIG/1.E06)*(1.+ALOG(ZA)/(1.-ZA)   B  280
     1)/(-2.)                                                              B  285
    3 CONTINUE                                                             B  290
    4 CONTINUE                                                             B  295
C***  MOMENTS OF SDENS                                                     B  300
      ZD=0.                                                                B  305
      ZB=1.                                                                B  310
      IF (ZA.GT.0.) ZB=1.+(ZA*ALOG(ZA))/(1.-ZA)                            B  315
      ZE=V(1)*SIGEB(25,1)                                                  B  320
      ZF=V(NVM)*SIGEB(25,1)                                                B  325
      ZG=V(NVM)/V(1)                                                       B  330
      IF (ZA.GT.0.) ZD=(.5*ZB*ZG)/(1.+ALOG(ZA)/(1.-ZA))                    B  335
      EXM(1,1)=(2.*(1.-.5*ZB*ZG*AMASS(1)))/(ZB*ZF)                         B  340
      EXM(2,1)=(2.*((3.*AMASS(1)*(AMASS(1)+1.))/(3.*AMASS(1)-1.)-2.*AMAS   B  345
     1S(1)*ZG*(1.+ZD)))/(ZB*ZF*ZF)                                         B  350
      ZA=EXM(1,1)*1.E06                                                    B  355
      ZB=EXM(2,1)*1.E12                                                    B  360
      EXM(1,1)=0.                                                          B  365
      EXM(2,1)=0.                                                          B  370
      DO 5 IA=1,NMO                                                        B  375
      IF (NMOM(IA).EQ.1) EXM(IA,1)=ZA                                      B  380
      IF (NMOM(IA).EQ.2) EXM(IA,1)=ZB                                      B  385
      DO 5 IB=1,2                                                          B  390
    5 IF (EXM(IA,IB).GT.0.) ERR(IA,IB)=CORMOM(IA,IB+4)/EXM(IA,IB)-1.       B  395
      RETURN                                                               B  400
      END                                                                  B  405
```


****** GENRAT ******

```
      SUBROUTINE GENRAT                                                    C    5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G(   C   10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)   C   15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SDENS(4   C   20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(   C   25
     4201),DE(201),EII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2   C   30
     5(204),FVAR3(204),FVAR4(204)                                          C   35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2   C   40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21   C   45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),   C   50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI   C   55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI   C   60
     5GFB(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),BSD(6),BSDR   C   65
```

```
      2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT   C    85
      3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE        C    90
       REAL LEAK,NORM                                                      C    95
       DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6  C   100
      1)                                                                   C   105
       EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT)  C   110
      1, (FISS,DIST)                                                       C   115
C***                                                                       C   120
C***   GENRAT GENERATES NEW ROWS OF THE TRANSITION MATRIX USING EQS. 14    C   125
C***   AND 15, AFTER TESTING TO SEE WHICH ROWS SATISFY EQ. 44 FOR FOR      C   130
C***   THE TIME STEP IN USE.                                               C   135
C***                                                                       C   140
C***   JROW IS THE NUMBER OF ROWS THAT HAVE BEEN DEFINED.                  C   145
C***   KROW IS THE NEXT ROW TO BE DEFINED.                                 C   150
       DO 1 IA=KROW,NM                                                     C   155
       COMP=G(IA)*DDT*(2.**(I-1))                                          C   160
       IF (COMP.LT.CRIT) GO TO 2                                           C   165
       ZA=EXP(-COMP)                                                       C   170
       P(IA,IA)=P(IA,IA)+(1.-P(IA,IA))*ZA                                  C   175
       ZB=1.-ZA                                                            C   180
       JROW=JROW+1                                                         C   185
       ID=IA+1                                                             C   190
       DO 1 IB=ID,NP3                                                      C   195
       P(IA,IB)=ZB*P(IB,IA)                                                C   200
     1 P(IB,IA)=0.                                                         C   205
     2 CONTINUE                                                            C   210
       KROW=JROW+1                                                         C   215
       RETURN                                                              C   220
       END                                                                 C   225
```


**** GENTIM ****

```
       SUBROUTINE GENTIM                                                   D     5
       COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G(  D    10
      171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)  D    15
      2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SDENS(4  D    20
      300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(  D    25
      4201),DE(201),EII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2  D    30
      5(204),FVAR3(204),FVAR4(204)                                         D    35
       COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2  D    40
      16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21  D    45
      2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),  D    50
      3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI  D    55
      4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI  D    60
      5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDR  D    65
      6(2),RSDX(2)                                                         D    70
       COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,I  D    75
      1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N  D    80
      2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT  D    85
      3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE        D    90
       REAL LEAK,NORM                                                      D    95
       DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6  D   100
      1)                                                                   D   105
       EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT)  D   110
      1, (FISS,DIST)                                                       D   115
C***                                                                       D   120
C***   GENTIM (1) DETERMINES THE OPERATING TIME STEP WIDTH FROM THE        D   125
C***   VALUES OF OPCRIT AND THE STATE DECAY CONSTANT AT THE STATE WITH     D   130
C***   THE GREATEST POPULATION  (2) DETERMINES GENERATING TIME AND         D   135
C***   PARAMETERS EACH TIME A NEW REAL TRANSITION PROBABILITY ARRAY IS      D   140
C***   GENERATED.  REFERENCE EQS. 44-46.                                   D   145
C***                                                                       D   150
       IF (L(2).EQ.0) GO TO 3                                              D   155
       IF (L(11).EQ.1) GO TO 2                                             D   160
C***   DISTRIBUTED SOURCE IS TESTED FOR LOCATION OF PEAK.                  D   165
```

```
      ZA=PTP(2)                                                          D  170
      IF (ZA.EQ.0.) GO TO 2                                              D  175
      DO 1 IA=3,NM                                                       D  180
      IF (PTP(IA).LT.ZA) GO TO 1                                         D  185
      ZA=PTP(IA)                                                         D  190
      IPEAK=IA                                                           D  195
    1 CONTINUE                                                           D  200
C***  DEFINE FIRST OPERATING TIME STEP.                                  D  205
    2 DT(1)=OPCRIT/G(IPEAK-NTOP)                                         D  210
C***  GENERATING TIME ROUTINE.                                           D  215
C***  INITIAL ESTIMATE OF GENERATING TIME.                               D  220
    3 ZA=CRIT/G(IPEAK-NTOP)                                              D  225
      ZB=(ALOG10(DT(NTIME)/ZA)/ALOG10(2.))                               D  230
C***  GENERATING INDEX (N IN EQ. 46)                                     D  235
      IND=INT(ZB)                                                        D  240
C***  FINAL ESTIMATE OF GENERATING TIME.                                 D  245
      DDT=DT(NTIME)/(2.**IND)                                            D  250
      JROW=0                                                             D  255
      KROW=1                                                             D  260
      IF (L(11).EQ.0) JROW=1                                             D  265
      IF (L(11).EQ.0) KROW=2                                             D  270
      IF (IND.LE.1) WRITE (6,4) IND                                      D  275
      IF (IND.GT.1) WRITE (6,5) IND,DDT,IPEAK,G(IPEAK-NTOP)              D  280
      RETURN                                                             D  285
C***                                                                     D  290
    4 FORMAT ('0',///////,'   GENERATING INDEX =',I3,' AND ROW GENERATIO  D  295
     1N ROUTINE HAS BEEN BYPASSED. ',///////)                            D  300
    5 FORMAT ('0',/////,' GENERATING ROUTINE IS BEING CALLED FOR',I3,' I  D  305
     1TERATIONS BEGINNING AT TIME DDT =',1PE10.3,' SECONDS.',/,' DDT IS   D  310
     2DEFINED FOR VIRTUAL STATE',I4,' FOR WHICH THE DECAY CONSTANT IS',1  D  315
     3PE10.3,'.',/////)                                                  D  320
      END                                                                D  325
```


****** GETIT (******

```
      SUBROUTINE GETIT (NO,NC,LASTNO)                                    E    5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G(  E   10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)  E   15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SCENS(4  E   20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(  E   25
     4201),DE(201),EII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2  E   30
     5(204),FVAR3(204),FVAR4(204)                                        E   35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),EGSF(2  E   40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21  E   45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),  E   50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI  E   55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI  E   60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSER  E   65
     6(2),RSDX(2)                                                        E   70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,I  E   75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JRCW,KROW,LL,MAXR,MAXT,MAXV,N,N  E   80
     2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT  E   85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE       E   90
      REAL LEAK,NORM                                                     E   95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6 E  100
     1)                                                                  E  105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT) E  110
     1, (FISS,DIST)                                                      E  115
      COMMON NUM1(5),NUM2(5),NOMAX                                       E  120
      INTEGER NUM2*4                                                     E  125
C***  THIS SUBROUTINE RETRIEVES ISOTOPE AND CROSS SECTION DATA FROM      E  130
C***  EXTERNAL FILES AND PLACES IT IN APPROPRIATE LOCATIONS.             E  135
C***  DATA SETS ARE READ SEQUENTIALLY AND DISCARDED UNTIL THE DESIRED    E  140
C***  SET IS FOUND.                                                      E  145
C***                                                                     E  150
C***  NO = INDEX NUMBER OF DATA SET TO BE RETRIEVED, BETWEEN 1 AND NOMAX E  155
```

```
      IF (NO.GT.LASTNO) GO TO 1                                          E  175
      LASTNO=0                                                           E  180
      REWIND 1                                                           E  185
    1 IB=LASTNO+1                                                        E  190
      DO 2 IG=IB,NC                                                      E  195
      LASTNO=LASTNO+1                                                    E  200
    2 READ (1,3) NUM2(NC),ATOM(2*NC-1),ATOM(2*NC),AMASS(NC),(SIGTB(IC,NC  E  205
     1),IC=1,NGR),(SIGFB(IC,NC),IC=1,NGR),(SIGNB(IC,NC),IC=1,NGR),(SIGCB  E  210
     2(IC,NC),IC=1,NGR),(SIGEB(IC,NC),IC=1,NGR),(AMUB(IC,NC),IC=1,NGR),(  E  215
     3(H(IC,ID,NC),ID=1,12),IC=1,12),(((RSS(IC,ID,IE,NC),IC=1,NGR),ID=1,   E  220
     46),IE=1,4)                                                         E  225
      RETURN                                                             E  230
C***                                                                     E  235
    3 FORMAT (4(232A4))                                                  E  240
      END                                                                E  245
```

****** INCOND ******

```
      SUBROUTINE INCOND                                                  F    5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G(  F   10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)  F   15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SCENS(4  F   20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(  F   25
     4201),DE(201),EII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2  F   30
     5(204),FVAR3(204),FVAR4(204)                                        F   35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2  F   40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21  F   45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),  F   50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI  F   55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI  F   60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDR  F   65
     6(2),RSDX(2)                                                        F   70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,I  F   75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JRCW,KROW,LL,MAXR,MAXT,MAXV,N,N  F   80
     2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT  F   85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE        F   90
      REAL LEAK,NORM                                                     F   95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6 F  100
     1)                                                                  F  105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT) F  110
     1, (FISS,DIST)                                                      F  115
C***                                                                     F  120
C***  INCOND DEFINES AND NORMALIZES THE INITIAL STATE VECTOR AND         F  125
C***  COMPUTES NEUTRON YIELDS PER FISSION IN EACH STATE (ANUNOR).        F  130
C***                                                                     F  135
      IF (L(10).EQ.0) GO TO 18                                           F  140
      ZA=0.                                                              F  145
      ZB=0.                                                              F  150
      DO 1 IB=1,NM                                                       F  155
    1 ANUNOR(IB)=0.                                                      F  160
      DO 15 IA=1,NI                                                      F  165
      IC=AMASS(IA)-231.                                                  F  170
C***  CHECK TO SEE IF ISOTOPE IS FISSIONABLE.                            F  175
      IF (IC.LT.1) GO TO 15                                              F  180
      IF (IC.GT.11) GO TO 15                                             F  185
      GO TO (2,3,4,5,6,7,8,9,10,11,12), IC                               F  190
    2 ZA=1.95                                                            F  195
      ZB=.14E-06                                                         F  200
      GO TO 13                                                           F  205
    3 ZA=2.49                                                            F  210
      ZB=.13E-06                                                         F  215
      GO TO 13                                                           F  220
    4 ZA=2.37                                                            F  225
      ZB=.13E-06                                                         F  230
      GO TO 13                                                           F  235
```

```
      5 ZA=2.42                                                          F  240
        ZB=.135E-06                                                      F  245
        GO TO 13                                                         F  250
      6 ZA=2.38                                                          F  255
        ZB=.135E-06                                                      F  260
C***    THERE IS NO FISSILE ISOTOPE OF MASS 237.                         F  265
      7 GO TO 13                                                         F  270
      8 ZA=2.4                                                           F  275
        ZB=.14E-06                                                       F  280
        GO TO 13                                                         F  285
      9 ZA=2.87                                                          F  290
        ZB=.13E-06                                                       F  295
        GO TO 13                                                         F  300
     10 ZA=2.8                                                           F  305
        ZB=.13E-06                                                       F  310
        GO TO 13                                                         F  315
     11 ZA=2.96                                                          F  320
        ZB=.135E-06                                                      F  325
        GO TO 13                                                         F  330
     12 ZA=2.85                                                          F  335
        ZB=.135E-06                                                      F  340
     13 DO 14 IB=1,NM                                                    F  345
C***    DEFINES THE AVERAGE NEUTRON YIELD PER FISSION IN EACH STATE.     F  350
C***    A FISSION RATE WEIGHTED AVERAGE OVER THE ISOTOPES PRESENT.       F  355
     14 ANUNOR(IB)=ANUNOR(IB)+SIGF(IB,IA)*(ZA+ZB*EII(IB+NTOP))           F  360
     15 CONTINUE                                                         F  365
        DO 17 IA=1,NM                                                    F  370
        ZA=0.                                                            F  375
        DO 16 IB=1,NI                                                    F  380
     16 ZA=ZA+SIGF(IA,IB)                                                F  385
        IF (ZA.NE.0) ANUNOR(IA)=ANUNOR(IA)/ZA                            F  390
     17 CONTINUE                                                         F  395
     18 CONTINUE                                                         F  400
        IF (L(2).EQ.0) GO TO 25                                          F  405
        IF (L(9).EQ.1) GO TO 25                                          F  410
        ZD=0.                                                            F  415
        IF (L(11).EQ.1) GO TO 20                                         F  420
        IF (L(8).EQ.1) GO TO 21                                          F  425
C***    DEFINES SOURCE VECTOR ACCORDING TO THE WATT FISSION SPECTRUM.    F  430
        DO 19 IA=2,NVM                                                   F  435
        ZA=(E(IA-1)+E(IA))*.0000005                                      F  440
        ZB=-ZA/0.965                                                     F  445
        ZC=SQRT(2.29*ZA)                                                 F  450
        PTP(IA)=(EXP(ZB))*SINH(ZC)*DE(IA)                                F  455
     19 ZD=ZD+PTP(IA)                                                    F  460
        ZD=1./ZD                                                         F  465
        GO TO 23                                                         F  470
C***    DELTA FUNCTION SOURCE                                            F  475
     20 PTP(1)=1.                                                        F  480
        GO TO 23                                                         F  485
     21 ZD=0.                                                            F  490
        DO 22 IA=2,NVM                                                   F  495
     22 ZD=ZD+PTP(IA)                                                    F  500
        IF (ZD.GT.0.) ZD=1./ZD                                           F  505
     23 CONTINUE                                                         F  510
C***    NORMALIZE SOURCE VECTOR                                          F  515
        DO 24 IA=2,NVM                                                   F  520
     24 PTP(IA)=PTP(IA)*ZD                                               F  525
        WRITE (6,26)                                                     F  530
        WRITE (6,27) (PTP(IA),IA=1,NVM)                                  F  535
     25 CONTINUE                                                         F  540
        RETURN                                                           F  545
C***                                                                     F  550
C***                                                                     F  555
     26 FORMAT ('1',////,' -----SOURCE VECTOR POP(I,1) (NEUTRONS PER STATE F  560
       1)-----',///)                                                     F  565
     27 FORMAT (1P10E10.3)                                               F  570
        END                                                              F  575
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      SUBROUTINE INTERP                                                 G    5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G(  G   10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)  G   15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SCENS(4  G   20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(  G   25
     4201),DE(201),EII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2  G   30
     5(204),FVAR3(204),FVAR4(204)                                       G   35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2  G   40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21  G   45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),  G   50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI  G   55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI  G   60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDR  G   65
     6(2),RSDX(2)                                                       G   70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,I  G   75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JRCW,KROW,LL,MAXR,MAXT,MAXV,N,N  G   80
     2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT  G   85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE      G   90
      REAL LEAK,NORM                                                    G   95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6  G  100
     1)                                                                 G  105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT)  G  110
     1, (FISS,DIST)                                                     G  115
C***                                                                    G  120
C***  INTERP COMPUTES LINEARLY INTERPOLATED VALUES OF TIME DISTRIBUTIONS  G  125
C***  ON A UNIFORM TIME MESH OF 200 POINTS.  THE FIRST 20 POINTS ARE    G  130
C***  SPACED AT 1/4 THE SEPARATION OF THE REMAINING POINTS.             G  135
C***                                                                    G  140
      DO 1 IA=1,6                                                       G  145
      DO 1 IB=1,200                                                     G  150
    1 DINT(IB,IA)=0.                                                    G  155
C***  CALCULATE TIME STEP WIDTH.                                        G  160
      Z=(TIM(NT)-TIM(1))/200.                                           G  165
      ZA=ALOG10(Z)                                                      G  170
      ZB=AINT(ZA)                                                       G  175
      ZA=10.**(ZA-ZB+1.)                                                G  180
      DTI=10.                                                           G  185
      IF (ZA.LE.5.) DTI=5.                                              G  190
      IF (ZA.LE.2.) DTI=2.                                              G  195
      DTI=DTI*(10.**(ZB-1.))                                            G  200
C***  CALCULATE THE NUMBER OF ITERATIONS REQUIRED                       G  205
      NIT=INT((TIM(NT)-TIM(1))/DTI)+15                                  G  210
      IF (NIT.GT.200) DTI=DTI*2.                                        G  215
      IF (NIT.LT.65) DTI=DTI/2.                                         G  220
      NIT=INT((TIM(NT)-TIM(1))/DTI)+15                                  G  225
      DO 2 IA=1,20                                                      G  230
      ZA=IA                                                             G  235
    2 TINT(IA)=ZA*DTI*.25+TIM(1)                                        G  240
      DO 3 IA=21,NIT                                                    G  245
      ZA=IA-15                                                          G  250
    3 TINT(IA)=ZA*DTI+TIM(1)                                            G  255
      IF (L(16).EQ.1) GO TO 6                                           G  260
C***  INTERPOLATION OF DENSITY                                          G  265
      NB=1                                                              G  270
      DO 5 IA=1,NIT                                                     G  275
      NBEG=NB                                                           G  280
      DO 4 IB=NBEG,NTM                                                  G  285
      IF (TIM(IB+1).LT.TINT(IA)) GO TO 4                                G  290
      DINT(IA,6)=DENS(IB)+(DENS(IB+1)-DENS(IB))*(TINT(IA)-TIM(IB))/(TIM(  G  295
     1IB+1)-TIM(IB))                                                    G  300
      NB=IB-1                                                           G  305
      GO TO 5                                                           G  310
    4 CONTINUE                                                          G  315
    5 CONTINUE                                                          G  320
    6 CONTINUE                                                          G  325
C***  INTERPOLATION OF ABSORBING STATE DISTRIBUTIONS                    G  330
      ID=1                                                              G  335
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      IE=5                                                              G  340
      IF (L(15).EQ.1) ID=5                                              G  345
      IF (L(17).EQ.1) ID=2                                              G  350
      IF (L(16).EQ.1) IE=4                                              G  355
      NB=1                                                              G  360
      DO 9 IA=1,NIT                                                     G  365
      NBEG=NB                                                           G  370
      DO 8 IB=NBEG,NTM                                                  G  375
      IF (TIMD(IB+1).LT.TINT(IA)) GO TO 8                               G  380
      ZA=(TINT(IA)-TIMD(IB))/(TIMD(IB+1)-TIM(IB))                       G  385
      DO 7 IC=ID,IE                                                     G  390
    7 DINT(IA,IC)=DIST(IB,IC)+(DIST(IB+1,IC)-DIST(IB,IC))*ZA            G  395
      NB=IB-1                                                           G  400
      GO TO 9                                                           G  405
    8 CONTINUE                                                          G  410
    9 CONTINUE                                                          G  415
      RETURN                                                            G  420
      END                                                               G  425
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****** LIBRAR ******

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      SUBROUTINE LIBRAR                                                 H    5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G(H   10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)H   15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SDENS(4H   20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(H   25
     4201),DE(201),EII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2H   30
     5(204),FVAR3(204),FVAR4(204)                                       H   35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2H   40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21H   45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),H   50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SIH   55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SIH   60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDRH   65
     6(2),RSDX(2)                                                       H   70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,IH   75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXI,MAXV,N,NH   80
     2A,ND,NGR,NF,NI,NIT,NM,NMC,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NTH   85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE      H   90
      REAL LEAK,NORM                                                    H   95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6H  100
     1)                                                                 H  105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT)H  110
     1, (FISS,DIST)                                                     H  115
C***                                                                    H  120
C***  THIS VERSION OF LIBRAR IS INTENDED FOR USE WITH THE ABN26 GROUP   H  125
C***  CROSS SECTION LIBRARY.                                            H  130
C***  BROAD GROUP MICROSCOPIC CROSS SECTIONS ARE CORRECTED FOR RESONANCEH  135
C***  SELF-SHIELDING AND CONVERTED TO MACROSCOPIC CROSS SECTIONS.  THE  H  140
C***  BROAD GROUP CROSS SECTIONS ARE USED TO DEFINE CROSS SECTIONS FOR  H  145
C***  EACH STATE.                                                       H  150
C***                                                                    H  155
      IF (L(2).EQ.0) GO TO 11                                           H  160
      DO 1 IA=1,NI                                                      H  165
    1 RHON(IA)=(RHO(IA)*.6023)/AMASS(IA)                                H  170
C***  STATEMENTS TO NUMBER 10 DEFINE MACROSCOPIC CROSS SECTIONS FOR     H  175
C***  BROAD GROUPS.  THESE STATEMENTS ARE EXECUTED THE FIRST TIME       H  180
C***  SUBROUTINE LIBRAR IS CALLED.                                      H  185
C***  THE ROUTINE EXTENDING TO FORTRAN STATEMENT 6 INTRODUCES RESONANCE H  190
C***  SELF-SHIELDING CORRECTIONS AND IS OPTIONAL.                       H  195
      DO 10 IA=1,NGR                                                    H  200
      SUM=0.                                                            H  205
      DO 2 IB=1,NI                                                      H  210
    2 SUM=SUM+RHON(IB)*SIGTB(IA,IB)                                     H  215
      DO 4 IB=1,NI                                                      H  220
      NFLAG=0                                                           H  225
      SARG(IB)=SUM/RHON(IB)-SIGTB(IA,IB)                                H  230
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      IF (SARG(IB).GT.1.) IZ=INT(ALOG10(SARG(IB)))+2                    H  240
      IF (SARG(IB).GT.1.0E05) IZ=6                                      H  245
      IF (SARG(IB).GT.1.0E05) NFLAG=1                                   H  250
      IF (NFLAG.EQ.1) WRITE (6,17) IB,IA                                H  255
      ZA=-IZ+2                                                          H  260
      DO 3 IC=1,4                                                       H  265
      RI(IC)=RSS(IA,2,IC,IB)+SARG(IB)*(RSS(IA,2,IC,IB)-RSS(IA,1,IC,IB)) H  270
      IF (IZ.GT.1) RI(IC)=RSS(IA,IZ,IC,IB)+(RSS(IA,IZ+1,IC,IB)-RSS(IA,IZ H  275
     1,IC,IB))*(ALOG10(SARG(IB))+ZA)                                    H  280
    3 CONTINUE                                                          H  285
C***  IF IZ=1 LINEAR INTERPOLATION, OTHERWISE LOGARITHMIC.              H  290
    4 SSTAR(IB)=SIGNB(IA,IB)+SIGFB(IA,IB)*RI(1)+SIGCB(IA,IB)*RI(2)+SIGEB H  295
     1(IA,IB)*RI(4)                                                     H  300
      SUM=0.                                                            H  305
      DO 5 IB=1,NI                                                      H  310
    5 SUM=SUM+RHON(IB)*SSTAR(IB)                                        H  315
      DO 7 IB=1,NI                                                      H  320
      SZERO(IB)=SUM/RHON(IB)-SSTAR(IB)                                  H  325
      IZ=1                                                              H  330
      IF (SZERO(IB).GT.1) IZ=INT(ALOG10(SZERO(IB)))+2                   H  335
      IF (SZERO(IB).GT.1.0E05) IZ=6                                     H  340
      ZA=-IZ+2                                                          H  345
      DO 6 IC=1,4                                                       H  350
      RI(IC)=RSS(IA,2,IC,IB)+SZERO(IB)*(RSS(IA,2,IC,IB)-RSS(IA,1,IC,IB)) H  355
      IF (IZ.GT.1) RI(IC)=RSS(IA,IZ,IC,IB)+(RSS(IA,IZ+1,IC,IB)-RSS(IA,IZ H  360
     1,IC,IB))*(ALOG10(SZERO(IB))+ZA)                                   H  365
    6 CONTINUE                                                          H  370
      SIGFB(IA,IB)=SIGFB(IA,IB)*RI(1)*RHON(IB)                          H  375
      SIGCB(IA,IB)=SIGCB(IA,IB)*RI(2)*RHON(IB)                          H  380
      SIGTB(IA,IB)=SIGTB(IA,IB)*RI(3)*RHON(IB)                          H  385
      SIGEB(IA,IB)=SIGEB(IA,IB)*RI(4)*RHON(IB)                          H  390
      SIGNB(IA,IB)=SIGNB(IA,IB)*RHON(IB)                                H  395
    7 CONTINUE                                                          H  400
      SIGTRB(IA)=0.                                                     H  405
      DO 8 IB=1,NI                                                      H  410
    8 SIGTRB(IA)=SIGTRB(IA)+SIGTB(IA,IB)-AMUB(IA,IB)*SIGEB(IA,IB)       H  415
      DB2B(IA)=BUCKLE/(3.*SIGTRB(IA))-((BUCKLE/SIGTRB(IA))**2)/5.       H  420
      SIGTBT(IA)=DB2B(IA)                                               H  425
      DO 9 IB=1,NI                                                      H  430
    9 SIGTBT(IA)=SIGTBT(IA)+SIGFB(IA,IB)+SIGCB(IA,IB)+SIGNB(IA,IB)+SCALE H  435
     1(IA,IB)*(1.+2./(3.*AMASS(IB))-AMUB(IA,IB))*SIGEB(IA,IB)           H  440
   10 CONTINUE                                                          H  445
C***  IN THE REMAINING STATEMENTS CROSS SECTIONS ARE DEFINED FOR STATES  H  450
C***  OF THE NEW REAL ARRAY                                             H  455
   11 DO 16 IA=1,NM                                                     H  460
      IZ=NG(IA+NTOP)                                                    H  465
      IF (IZ.EQ.0) GO TO 13                                             H  470
C***  IF REAL STATE IA (VIRTUAL STATE IA+NTOP) DOES NOT LIE ON A BROAD  H  475
C***  GROUP BOUNDARY THE NEXT NINE STATEMENTS ARE EXECUTED.             H  480
      DO 12 IB=1,NI                                                     H  485
      AMU(IA,IB)=AMUB(IZ,IB)                                            H  490
      SIGC(IA,IB)=SIGCB(IZ,IB)                                          H  495
      SIGN(IA,IB)=SIGNB(IZ,IB)                                          H  500
      SIGF(IA,IB)=SIGFB(IZ,IB)                                          H  505
   12 SIGE(IA,IB)=SIGEB(IZ,IB)                                          H  510
      SIGT(IA)=SIGTBT(IZ)                                               H  515
      DB2(IA)=DB2B(IZ)                                                  H  520
      SIGTR(IA)=SIGTRB(IZ)                                              H  525
      GO TO 16                                                          H  530
C***  IF REAL STATE IA LIES ON A GROUP BOUNDARY ENERGY WEIGHTED AVERAGE  H  535
C***  CROSS SECTIONS ARE COMPUTED.                                      H  540
   13 IY=IA+NTOP-1                                                      H  545
      W1=(E(IY)-EABN(NG(IY)))/(E(IY)-E(IY+1))                           H  550
      W2=(EABN(NG(IY))-E(IY+1))/(E(IY)-E(IY+1))                         H  555
      IY=NG(IY)                                                         H  560
      DO 14 IB=1,NI                                                     H  565
      AMU(IA,IB)=W1*AMUB(IY,IB)+W2*AMUB(IY+1,IB)                        H  570
      SIGC(IA,IB)=W1*SIGCB(IY,IB)+W2*SIGCB(IY+1,IB)                     H  575
      SIGN(IA,IB)=W1*SIGNB(IY,IB)+W2*SIGNB(IY+1,IB)                     H  580
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      SIGF(IA,IB)=W1*SIGFB(IY,IB)+W2*SIGFR(IY+1,IB)                          H   585
   14 SIGS(IA,IB)=SIGFB(IY,IB)                                               H   590
      DB2(IA)=W1*DB2B(IY)+W2*DB2B(IY+1)                                      H   595
      SIGTR(IA)=W1*SIGTRB(IY)+W2*SIGTRB(IY+1)                                H   600
      SIGT(IA)=DB2(IA)                                                       H   605
      DO 15 IB=1,NI                                                          H   610
   15 SIGT(IA)=SIGT(IA)+SIGC(IA,IB)+SIGN(IA,IB)+SCALE(IY,IB)*(1.+2./(3.*    H   615
     1AMASS(IB))-AMU(IA,IB))*SIGE(IA,IB)+SIGF(IA,IB)                         H   620
   16 CONTINUE                                                               H   625
      RETURN                                                                 H   630
C***                                                                         H   635
   17 FORMAT ('0','**** CAUTION ****',//,'SIGMAZERO EXCEEDS 1.0E 05 FOR      H   640
     1ISOTOPE NUMBER',I2,' IN GROUP NUMBER',I3,'.  THIS LIES OUTSIDE THE     H   645
     2 BOUNDS OF',/,'THE RESONANT SELFSHIELDING TABLE THAT ACCOMPANIES T     H   650
     3HIS PROGRAM.  A DEFAULT VALUE OF 1<0E 04 IS ASSUMED',/,'BUT THE US     H   655
     4ER SHOULD REFER TO THE ABN 26 GROUP LISTING TO SEE IF THIS ASSUMPT     H   660
     5I/N IS ACCEPTABLE.',///)                                               H   665
      END                                                                    H   670
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**** MODPLT ****

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      SUBROUTINE MODPLT                                                      I     5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G(     I    10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)     I    15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SCENS(4     I    20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(     I    25
     4201),DE(201),EII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2     I    30
     5(204),FVAR3(204),FVAR4(204)                                            I    35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2     I    40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21     I    45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),     I    50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI     I    55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI     I    60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDR     I    65
     6(2),RSDX(2)                                                            I    70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,I     I    75
     1A,IB,IG,ID,IE,IG,IH,IND,IPEAK,J,JJ,JRCW,KROW,LL,MAXR,MAXT,MAXV,N,N     I    80
     2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT     I    85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE           I    90
      REAL LEAK,NORM                                                         I    95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6     I   100
     1)                                                                      I   105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT)     I   110
     1, (FISS,DIST)                                                          I   115
C***                                                                         I   120
C***  MODPLT PROVIDES A ROUGH PLOT OF THE LETHARGY DEPENDENT NEUTRON         I   125
C***  DENSITY, ONE POINT FOR EACH STATE IN REAL VECTOR WITH NO               I   130
C***  CORRECTION FOR NON-UNIFORMITY OF STATE WIDTHS.                         I   135
C***                                                                         I   140
      DIMENSION M(103), MB(103), SC(11), ISYM(2), MP(103), MBP(103)          I   145
      DATA ISYM/1H*,1H /,IP,IM/1H+,1H-/                                      I   150
      DATA II/1HI/                                                           I   155
C***  REDEFINE FUNCTION AND DETERMINE RANGE.                                 I   160
      YMAX=1.                                                                I   165
      YMIN=0.                                                                I   170
C***  TOP BORDER                                                             I   175
      DO 1 IA=1,103                                                          I   180
    1 M(IA)=IM                                                               I   185
      DO 2 IA=2,103,10                                                       I   190
    2 M(IA)=IP                                                               I   195
      DELT=(YMAX-YMIN)*.1                                                    I   200
      SC(1)=YMIN                                                             I   205
      DO 3 IA=2,11                                                           I   210
    3 SC(IA)=SC(IA-1)+DELT                                                   I   215
      WRITE (6,9) SC                                                         I   220
      WRITE (6,10) M                                                         I   225
```

```
      OTHER=-YMIN*SCAL+2.5                                                  I  235
      DO 4 IA=2,102                                                         I  240
      MB(IA)=IM                                                             I  245
      MBP(IA)=IM                                                            I  250
      MP(IA)=ISYM(2)                                                        I  255
    4 M(IA)=ISYM(2)                                                         I  260
      MP(1)=IM                                                              I  265
      MP(103)=IM                                                            I  270
      MB(1)=IM                                                              I  275
      MBP(1)=IM                                                             I  280
      MBP(103)=IM                                                           I  285
      DO 5 IA=2,102,20                                                      I  290
      MP(IA)=II                                                             I  295
      MBP(IA)=II                                                            I  300
      M(IA)=II                                                              I  305
    5 MB(IA)=II                                                             I  310
C***  PRINT BODY OF GRAPH                                                   I  315
      DO 6 IA=2,NM                                                          I  320
      IB=IA+NTOP                                                            I  325
      NP=POP(IA,1)*SCAL/DU(IB)+OTHER                                        I  330
      IF (NP.LT.2) NP=2                                                     I  335
      IF (NP.GT.102) NP=102                                                 I  340
      M(NP)=ISYM(1)                                                         I  345
      MB(NP)=ISYM(1)                                                        I  350
      IC=10*(IB/10)                                                         I  355
      IF (IC.EQ.IB) WRITE (6,11) U(IB),MB,IB                                I  360
      IF (IC.NE.IB) WRITE (6,12) M,IB                                       I  365
      M(NP)=MP(NP)                                                          I  370
    6 MB(NP)=MBP(NP)                                                        I  375
C***  BOTTOM BORDER                                                         I  380
      DO 7 IA=1,103                                                         I  385
    7 M(IA)=IM                                                              I  390
      DO 8 IA=2,103,10                                                      I  395
    8 M(IA)=IP                                                              I  400
      WRITE (6,10) M                                                        I  405
      WRITE (6,13) SC                                                       I  410
      RETURN                                                                I  415
C***                                                                        I  420
C***                                                                        I  425
    9 FORMAT ('0',////,16X,1P11E10.2)                                       I  430
   10 FORMAT (10X,' LETHARGY  ',103A1)                                      I  435
   11 FORMAT (F21.3,103A1,I3)                                               I  440
   12 FORMAT (' ',20X,103A1,I3)                                             I  445
   13 FORMAT (' ',16X,1P11E10.2,////)                                       I  450
      END                                                                   I  455
```

**** MOMENT ****

```
      SUBROUTINE MOMENT                                                     J    5
      COMMON P(74,74),POP(74,2),PIP(204),FLUX(200),SFLUX(200),RR(200),G(    J   10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)    J   15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SCENS(4    J   20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),F(    J   25
     4201),DE(201),EII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2    J   30
     5(204),FVAR3(204),FVAR4(204)                                           J   35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2    J   40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),FXM(21    J   45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),    J   50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI    J   55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI    J   60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDR    J   65
     6(2),RSDX(2)                                                           J   70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,I    J   75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N    J   80
     2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT    J   85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE          J   90
      REAL LEAK,NORM                                                        J   95
```

```
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6
     1)                                                                 J  100
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT) J  105
     1, (FISS,DIST)                                                     J  110
C***                                                                    J  115
C***  MOMENT COMPUTES:  (1) UP TO 21 MOMENTS OF TIME DEPENDENT DISTRIB- J  120
C***  UTIONS, (2) EXPONENTIAL EXTRAPOLATION CORRECTIONS TO THE TIME     J  125
C***  MOMENTS, (3) MULTIPLICATION CONSTANT, AND (4) FIRST ENERGY MOMENTS J  130
C***  OF STEADY STATE CORE AND LEAKAGE SPECTRA.                         J  135
C***                                                                    J  140
      IPEAK=1                                                           J  145
C***  CLEAR TRANSITION MATRIX FOR STORAGE OF NEW VARIABLES.             J  150
      DO 1 IA=1,MAXR                                                    J  155
      DO 1 IB=1,MAXR                                                    J  160
    1 P(IA,IB)=0.                                                       J  165
C***  TIMD IS DEFINED AT MID-STEP FOR ABSORBING TRANSITIONS.            J  170
      DO 2 IA=1,NTM                                                     J  175
    2 TIMD(IA)=.5*(TIM(IA+1)+TIM(IA))                                   J  180
      TIMD(NT)=TIMD(NTM)*2.-TIMD(NTM-1)                                 J  185
      IF (L(16).EQ.1) GO TO 10                                          J  190
C***  TIME STEP WIDTHS                                                  J  195
      DO 3 IA=2,NTM                                                     J  200
    3 DTIM(IA)=TIMD(IA+1)-TIMD(IA)                                      J  205
C***  MOMENTS OF NEUTRON DENSITY IN STATE NVM.  DENS IS TEMPORARILY     J  210
C***  RENORMALIZED TO AN AMPLITUDE THAT MINIMIZES TRUNCATION AND ROUND- J  215
C***  OFF ERRORS AND UNDERFLOW OR OVERFLOW ERRORS.                      J  220
C***  FIND PEAK OF DENSITY                                              J  225
      DO 4 IA=20,NTM                                                    J  230
      IF (DENS(IA+1).LT.DENS(IA)) GO TO 5                               J  235
    4 CONTINUE                                                          J  240
    5 IPEAK=IA                                                          J  245
C***  RENORMALIZE TO UNIT TIME AT PEAK                                  J  250
      ZA=TIM(IPEAK)                                                     J  255
      DO 6 IA=1,NT                                                      J  260
      TIM(IA)=TIM(IA)/ZA                                                J  265
    6 DENS(IA)=DENS(IA)*ZA                                              J  270
      ID=5                                                              J  275
      IE=5                                                              J  280
C***  COMPUTE FIRST ESTIMATE OF MOMENTS (AMOM)                          J  285
      DO 8 IA=1,NMO                                                     J  290
      ZD=0.                                                             J  295
      ZE=0.                                                             J  300
      IC=NMOM(IA)                                                       J  305
      DO 7 IB=2,NTM                                                     J  310
    7 ZD=ZD+DENS(IB)*DTIM(IB)*(TIM(IB)**IC)                             J  315
    8 AMOM(IA,6)=ZD                                                     J  320
      DO 9 IA=1,NT                                                      J  325
    9 TIM(IA)=TIM(IA)*ZA                                                J  330
C***  MOMENTS OF REMAINING TIME DEPENDENT DISTRIBUTIONS.                J  335
   10 CONTINUE                                                          J  340
C***  TIME STEP WIDTHS                                                  J  345
      DO 11 IA=1,NTM                                                    J  350
   11 DTIM(IA)=TIM(IA+1)-TIM(IA)                                        J  355
      DTIM(NT)=DTIM(NTM)                                                J  360
C***  RENORMALIZE TO UNIT TIME = SQRT OF PRODUCT OF SMALLEST AND LARGEST J  365
C***  VALUES OF TIMD                                                    J  370
      ZC=SQRT(TIMD(2)*TIMD(NTM))                                        J  375
      IE=5                                                              J  380
      ID=5                                                              J  385
      IF (L(17).EQ.1) ID=2                                              J  390
      IF (L(16).EQ.1) ID=1                                              J  395
      IF (L(16).EQ.1) IE=4                                              J  400
C***  IF ONLY SDENS IS RENORMALIZED UNIT TIME = TIME OF PEAK            J  405
      IF (ID.EQ.5.AND.IE.EQ.5) ZC=TIMD(IPEAK)                           J  410
      DO 12 IA=ID,IE                                                    J  415
      DO 12 IB=1,NT                                                     J  420
   12 DIST(IB,IA)=DIST(IB,IA)*ZC                                        J  425
      ZC=1./ZC                                                          J  430
      DO 13 IA=1,NT                                                     J  435
   13 TIMD(IA)=TIMD(IA)*ZC                                              J  440
```

```
C***  CALCULATE MOMENTS                                                    J  450
      DO 14 IA=1,NMO                                                       J  455
      IG=NMOM(IA)                                                          J  460
      DO 14 IB=2,NTM                                                       J  465
      ZC=DTIM(IB)*(TIMD(IB)**IG)                                           J  470
      DO 14 IC=ID,IE                                                       J  475
   14 AMOM(IA,IC)=AMOM(IA,IC)+DIST(IB,IC)*ZC                               J  480
      IF (L(16).EQ.0) IE=6                                                 J  485
C***  CALCULATE EXTRAPOLATION CORRECTIONS                                  J  490
      DO 18 IA=ID,IE                                                       J  495
      DO 15 IB=1,NMO                                                       J  500
   15 CORMOM(IB,IA)=AMOM(IB,IA)                                            J  505
      IF (DIST(NT-2,IA).LE.0.) GO TO 18                                    J  510
      Z1=DIST(NT-6,IA)/DIST(NT-2,IA)                                       J  515
      Z2=(ALOG(Z1)*ZA)/(TIM(NT-2)-TIM(NT-6))                               J  520
      IF (IA.LE.5) Z2=(ALOG(Z1))/(TIMD(NT-2)-TIMD(NT-6))                   J  525
      Z3=1.+DIST(NT-2,IA)/Z2                                               J  530
      Z4=Z2*TIM(NT-2)/ZA                                                   J  535
      IF (IA.LE.5) Z4=Z2*TIMD(NT-2)                                        J  540
      DO 17 IB=1,NMO                                                       J  545
      IF (NMOM(IB).LE.0) GO TO 17                                          J  550
      Z5=0.                                                                J  555
      IG=NMOM(IB)+1                                                        J  560
      DO 16 IC=1,IG                                                        J  565
      IH=IG-IC                                                             J  570
      ZF=IH+1                                                              J  575
   16 Z5=Z5+(Z4**(IH))/GAMMA(ZF)                                           J  580
      Z6=IG                                                                J  585
      ZW=ZA                                                                J  590
      IF (IA.LE.5) ZW=1./ZC                                                J  595
      CORMOM(IB,IA)=(CORMOM(IB,IA)+(DIST(NT-2,IA)*ZW*GAMMA(Z6)*Z5)/(Z2**   J  600
     1IG))/Z3                                                              J  605
   17 CONTINUE                                                             J  610
   18 CONTINUE                                                             J  615
C***  AMOM IS REDEFINED TO BE THE TRUNCATION CORRECTION                    J  620
      DO 19 IA=1,6                                                         J  625
      DO 19 IB=1,NMO                                                       J  630
   19 AMOM(IB,IA)=CORMOM(IB,IA)-AMOM(IB,IA)                                J  635
C***  RE-ESTABLISH PROPER NORMALIZATION                                    J  640
      ZC=1./ZC                                                             J  645
      DO 20 IA=1,NT                                                        J  650
   20 TIMD(IA)=TIMD(IA)*ZC                                                 J  655
      DO 21 IA=1,NMO                                                       J  660
      Z1=((ZA*1.E06)**(NMOM(IA)-1))*1.E06                                  J  665
      Z3=((ZC*1.E06)**(NMOM(IA)-1))*1.E06                                  J  670
      AMOM(IA,6)=AMOM(IA,6)*Z1                                             J  675
      CORMOM(IA,6)=CORMOM(IA,6)*Z1                                         J  680
      DO 21 IB=1,5                                                         J  685
      AMOM(IA,IB)=AMOM(IA,IB)*Z3                                           J  690
   21 CORMOM(IA,IB)=CORMOM(IA,IB)*Z3                                       J  695
      ZA=1./ZA                                                             J  700
      ZC=1./ZC                                                             J  705
      DO 22 IA=1,NT                                                        J  710
      DENS(IA)=DENS(IA)*ZA                                                 J  715
      DO 22 IB=1,5                                                         J  720
   22 DIST(IA,IB)=DIST(IA,IB)*ZC                                           J  725
C***  ADD EXTRAPOLATION CORRECTION TO ESTIMATE OF MULTIPLICATION CONSTAN   J  730
      IF (L(10).EQ.1) EFFK=ESTK*(1.+(FISS(NT)/(ALOG(FISS(NT-4)/FISS(NT))   J  735
     1))*(TIM(NT)-TIM(NT-4)))                                              J  740
C***  FLUX MEAN ENERGY                                                     J  745
      CCENER=0.                                                            J  750
      CSENER=0.                                                            J  755
      DO 23 IA=2,NM                                                        J  760
      CCENER=CCENER+FLUX(IA)*EII(IA)*DU(IA)                                J  765
   23 CSENER=CSENER+SFLUX(IA)*EII(IA)*DU(IA)                               J  770
      RETURN                                                               J  775
      END                                                                  J  780
```

```
      SUBROUTINE NORMAL                                                      K     5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),BR(200),C(     K    10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)     K    15
     2,CB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SDENS(4     K    20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),F(     K    25
     4201),DE(201),EII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2     K    30
     5(204),FVAR3(204),FVAR4(204)                                           K    35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2     K    40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21     K    45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),     K    50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI     K    55
     4GCB(26,5),SIGFBI(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTRT(26),SI     K    60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDR     K    65
     6(2),RSDX(2)                                                           K    70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,I     K    75
     1A,IB,IC,ID,IS,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N     K    80
     2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIMS,NTITLE,NTM,NT     K    85
     30P,NVIR,NVM,OPCRIT,SCRIT,SOCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE          K    90
      REAL LEAK,NORM                                                        K    95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6     K   100
     1)                                                                     K   105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT)     K   110
     1, (FISS,DIST)                                                         K   115
C***                                                                        K   120
C***  NORMAL NORMALIZES TIME DEPENDENT DISTRIBUTIONS AND FLUXES             K   125
C***                                                                        K   130
      DO 1 IA=1,LL                                                          K   135
      DENS(IA)=0.                                                           K   140
    1 SDENS(IA)=0.                                                          K   145
      DO 3 IA=1,5                                                           K   150
      NORM(IA)=0.                                                           K   155
      DO 2 IB=1,NTM                                                         K   160
    2 NORM(IA)=NORM(IA)+DIST(IB,IA)                                         K   165
      IF (NORM(IA).GT.0.) NORM(IA)=1./NORM(IA)                              K   170
    3 CONTINUE                                                              K   175
      DO 4 IB=1,NTM                                                         K   180
      DO 4 IA=1,5                                                           K   185
      TDI=1./(TIM(IB+1)-TIM(IB))                                            K   190
    4 DIST(IB,IA)=DIST(IB,IA)*NORM(IA)*TDI                                  K   195
      DO 5 IA=1,5                                                           K   200
    5 DIST(NT,IA)=DIST(NT,IA)*NORM(IA)*TDI                                  K   205
      IF (L(10).EQ.1) ESTK=1./NORM(1)                                       K   210
      NORM(6)=0.                                                            K   215
      DO 6 IA=2,NTM                                                         K   220
    6 NORM(6)=NORM(6)+DENS(IA)*(TIM(IA+1)-TIM(IA-1))                        K   225
      IF (NORM(6).GT.0.) NORM(6)=2./NORM(6)                                 K   230
      DO 7 IA=1,NT                                                          K   235
    7 DENS(IA)=DENS(IA)*NORM(6)                                             K   240
C***  FLUX IS NORMALIZED IN LETHARGY.                                       K   245
      NORM(1)=0.                                                            K   250
      NORM(2)=0.                                                            K   255
      DO 8 IA=2,NVM                                                         K   260
      SFLUX(IA)=SFLUX(IA)*VII(IA)                                           K   265
      FLUX(IA)=FLUX(IA)*VII(IA)                                             K   270
      NORM(1)=NORM(1)+SFLUX(IA)                                             K   275
      NORM(2)=NORM(2)+FLUX(IA)                                              K   280
      SFLUX(IA)=SFLUX(IA)/DU(IA)                                            K   285
    8 FLUX(IA)=FLUX(IA)/DU(IA)                                              K   290
      IF (BUCKLE.GT.0.) NORM(1)=1./NORM(1)                                  K   295
      NORM(2)=1./NORM(2)                                                    K   300
      DO 9 IA=1,NVM                                                         K   305
      SFLUX(IA)=SFLUX(IA)*NORM(1)                                           K   310
    9 FLUX(IA)=FLUX(IA)*NORM(2)                                             K   315
      RETURN                                                                K   320
      END                                                                   K   325
```

```
      SUBROUTINE OUTPUT                                                 L     5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),C(  L    10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)  L    15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SCANS(4  L    20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(  L    25
     4201),DE(201),EII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2  L    30
     5(204),FVAR3(204),FVAR4(204)                                       L    35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2  L    40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21  L    45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),  L    50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI  L    55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI  L    60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDR  L    65
     6(2),RSDX(2)                                                       L    70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,I  L    75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N  L    80
     2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT  L    85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE      L    90
      REAL LEAK,NORM                                                    L    95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6  L   100
     1)                                                                 L   105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT  L   110
     1, (FISS,DIST)                                                     L   115
C***                                                                    L   120
C***  SUMMARIZES RESULTS                                                L   125
C***                                                                    L   130
      WRITE (6,47)                                                      L   135
      WRITE (6,48) (TITLE(I),I=1,NTITLE)                                L   140
      IF (L(10).EQ.1) WRITE (6,49) EFFK                                 L   145
      IF (L(10).EQ.1) WRITE (6,52) ESTK                                 L   150
      WRITE (6,50) CCENER,CSENER                                        L   155
      Z=TIM(NT)                                                         L   160
      ZA=SUMPOP                                                         L   165
      SUMPOP=0.                                                         L   170
      IB=NTOP+1                                                         L   175
      DO 1 IA=IB,NVM                                                    L   180
    1 SUMPOP=SUMPOP+PTP(IA)                                             L   185
      ZB=1.-PTP(NVIR)-PTP(NVIR+1)-PTP(NVIR+2)-PTP(NVIR+3)-SUMPOP        L   190
      WRITE (6,51) Z,PTP(NVIR+1),PTP(NVIR+2),PTP(NVIR+3),PTP(NVIR),E(NVI  L   195
     1R-1),SUMPOP,ZB,ZA                                                 L   200
      IB=NVIR+3                                                         L   205
      WRITE (6,53)                                                      L   210
      WRITE (6,54) (PTP(IA),IA=1,IB)                                    L   215
      WRITE (6,55)                                                      L   220
      WRITE (6,54) (FLUX(IA),IA=1,NVM)                                  L   225
      WRITE (6,56)                                                      L   230
      WRITE (6,54) (SFLUX(IA),IA=1,NVM)                                 L   235
      WRITE (6,23)                                                      L   240
      IF (L(16).EQ.1.OR.L(7).EQ.0) GO TO 3                              L   245
C***  CALCULATION OF RELATIVE STANDARD DEVIATION                        L   250
      DO 2 IA=5,6                                                       L   255
      RSD(IA)=SQRT(ABS(CORMOM(2,IA)/(CORMOM(1,IA)**2)-1.))              L   260
      RSDX(IA-4)=SQRT(ABS(EXM(2,IA-4)/(EXM(1,IA-4)**2)-1.))             L   265
    2 RSDR(IA-4)=RSD(IA)/RSDX(IA-4)-1.                                  L   270
    3 IF (L(15).EQ.1) GO TO 5                                           L   275
      DO 4 IA=1,4                                                       L   280
      IF (CORMOM(1,IA).GT.0.) RSD(IA)=SQRT(ABS(CORMOM(2,IA)/CORMOM(1,IA)  L   285
     1**2)-1.)                                                          L   290
    4 CONTINUE                                                          L   295
    5 CONTINUE                                                          L   300
      WRITE (6,24) EII(NVIR-1),E(NVIR-1)                                L   305
      WRITE (6,25) (NMOM(IA),CORMOM(IA,6),EXM(IA,2),AMOM(IA,6),ERR(IA,2)  L   310
     1,NMOM(IA),CORMOM(IA,5),EXM(IA,1),AMOM(IA,5),ERR(IA,1),IA=1,NMO)   L   315
      WRITE (6,26) RSD(6),RSDX(2),RSDR(2),RSD(5),RSDX(1),RSDR(1)        L   320
      WRITE (6,27)                                                      L   325
C***  OUTPUT-SPECIAL ROUTINE FOR COMPUTING RATIOS OF CALCULATED MOMENTS  L   330
      IF (L(7).EQ.0) GO TO 7                                            L   335
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```
      DO 6 IA=1,NMO                                                     L  340
    6 CORMOM(IA,6)=CORMOM(IA,6)/EXM(IA,2)                               L  345
      WRITE (6,28)                                                      L  350
      WRITE (6,29) (NMOM(IA),CORMOM(IA,6),IA=1,NMO)                     L  355
      IF (L(15).EQ.1) GO TO 8                                           L  360
    7 CONTINUE                                                          L  365
      WRITE (6,23)                                                      L  370
      WRITE (6,30)                                                      L  375
      WRITE (6,31) (NMOM(IA),(CORMOM(IA,IB),IB=1,4),(AMOM(IA,IP),IP=1,4)  L  380
     1,IA=1,NMO)                                                        L  385
      WRITE (6,32) (RSD(IA),IA=1,4)                                     L  390
    8 CONTINUE                                                          L  395
      IF (L(16).EQ.1) GO TO 10                                          L  400
C***  INTERPOLATED DISTRIBUTIONS                                        L  405
      IA=NIT                                                            L  410
      IB=IA/50+1                                                        L  415
      DO 9 IC=1,IB                                                      L  420
      ID=50*(IC-1)+1                                                    L  425
      IE=50*IC                                                          L  430
      IF (IC.EQ.IB) IE=IA                                               L  435
      WRITE (6,33) DTI                                                  L  440
      WRITE (6,34) (IG,TINT(IG),DINT(IG,6),DINT(IG,5),IG,IG=ID,IE)      L  445
    9 CONTINUE                                                          L  450
   10 CONTINUE                                                          L  455
      IF (L(15).EQ.1) GO TO 12                                          L  460
C***  INTERPOLATED DISTRIBUTIONS TO FISSION, LEAKAGE, CAPTURE, AND DEATH  L  465
      IA=NIT/50+1                                                       L  470
      DO 11 IB=1,IA                                                     L  475
      IC=50*(IB-1)+1                                                    L  480
      ID=50*IB                                                          L  485
      IF (IB.EQ.IA) ID=NIT                                              L  490
      WRITE (6,35) DTI                                                  L  495
      WRITE (6,36) (IE,TINT(IE),(DINT(IE,IG),IG=1,4),IE,IE=IC,ID)       L  500
   11 CONTINUE                                                          L  505
   12 CONTINUE                                                          L  510
C***  GROUP AVERAGED FLUXES                                             L  515
      ZA=SQRT(3.204/1.674663E-12)                                       L  520
      NORM(1)=0.                                                        L  525
      NORM(2)=0.                                                        L  530
      IC=NNG(1)                                                         L  535
      IG=NG(NVIR-1)                                                     L  540
      IF (IG.EQ.0) IG=NG(NVIR-2)                                        L  545
      IH=NG(3)                                                          L  550
      IF (IH.EQ.0) IH=NG(4)                                             L  555
      IF (IH.EQ.1) IH=2                                                 L  560
      IF (NG(2).NE.1) NNG(IH-1)=0                                       L  565
      IF (NG(2).EQ.0) NNG(IH-1)=1                                       L  570
      DO 14 IA=IH,IG                                                    L  575
      BGF(IA)=0.                                                        L  580
      BGSF(IA)=0.                                                       L  585
      IC=NNG(IA-1)+2                                                    L  590
      ID=NNG(IA)                                                        L  595
      DO 13 IB=IC,ID                                                    L  600
      BGF(IA)=BGF(IA)+FLUX(IB)*DU(IB)                                   L  605
      BGSF(IA)=BGSF(IA)+SFLUX(IB)*DU(IB)                                L  610
   13 CONTINUE                                                          L  615
      ZB=ALOG(EABN(IA-1)/EABN(IA))                                      L  620
      BGF(IA)=BGF(IA)+FLUX(IC-1)*ALOG(EABN(IA-1)/E(IC-1))+FLUX(IC+1)*AL  L  625
     1G(E(ID)/EABN(IA))                                                 L  630
      BGSF(IA)=BGSF(IA)+SFLUX(IC-1)*ALOG(EABN(IA-1)/E(IC-1))+SFLUX(IC+1)  L  635
     1*ALOG(E(ID)/EABN(IA))                                             L  640
      NORM(1)=NORM(1)+BGF(IA)                                           L  645
      NORM(2)=NORM(2)+BGSF(IA)                                          L  650
      BGF(IA)=BGF(IA)/ZB                                                L  655
      BGSF(IA)=BGSF(IA)/ZB                                              L  660
   14 CONTINUE                                                          L  665
      BGF(1)=0.                                                         L  670
      BGSF(1)=0.                                                        L  675
      IF (NG(2).NE.1) GO TO 16                                          L  680
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      DO 15 IB=2,ID                                                     L  690
      BGF(1)=BGF(1)+FLUX(IB)*DU(IB)                                     L  695
      BGSF(1)=BGSF(1)+SFLUX(IB)*DU(IB)                                  L  700
   15 CONTINUE                                                          L  705
      ZB=ALOG(10.E06/EABN(1))                                           L  710
      BGF(1)=BGF(1)+FLUX(ID+1)*ALOG(E(ID)/EABN(1))                      L  715
      BGSF(1)=BGSF(1)+SFLUX(ID+1)*ALOG(E(ID)/EABN(1))                   L  720
   16 CONTINUE                                                          L  725
      NORM(1)=1./(NORM(1)+BGF(1))                                       L  730
      NORM(2)=NORM(2)+BGSF(1)                                           L  735
      IF (NORM(2).NE.0.) NORM(2)=1./NORM(2)                             L  740
      BGF(1)=BGF(1)/ZB                                                  L  745
      BGSF(1)=BGSF(1)/ZB                                                L  750
      DO 17 IA=IH,IG                                                    L  755
      BGSF(IA)=BGSF(IA)*NORM(2)                                         L  760
      BGF(IA)=BGF(IA)*NORM(1)                                           L  765
   17 CONTINUE                                                          L  770
      WRITE (6,37)                                                      L  775
      IF (IH.EQ.2) WRITE (6,38) EABN(1),BGF(1),BGSF(1)                  L  780
      WRITE (6,39) (IA,EABN(IA-1),EABN(IA),BGF(IA),BGSF(IA),IA=IH,IG)   L  785
C***  DETAILED TIME DISTRIBUTIONS ARE WRITTEN OPTIONALLY                L  790
      IF (L(18).EQ.0) GO TO 21                                          L  795
      IF (L(18).EQ.1) GO TO 19                                          L  800
      IA=NT                                                             L  805
      IB=IA/50+1                                                        L  810
      DO 18 IC=1,IB                                                     L  815
      ID=50*(IC-1)+1                                                    L  820
      IE=50*IC                                                          L  825
      IF (IC.EQ.9) GO TO 18                                             L  830
      IF (IC.EQ.IB) IE=IA                                               L  835
      WRITE (6,40)                                                      L  840
      WRITE (6,41) (IG,TIM(IG),DENS(IG),SDENS(IG),IG,IG=ID,IE)          L  845
   18 CONTINUE                                                          L  850
      IF (L(15).EQ.1) GO TO 21                                          L  855
   19 CONTINUE                                                          L  860
      DO 20 IC=1,IB                                                     L  865
      ID=50*(IC-1)+1                                                    L  870
      IE=50*IC                                                          L  875
      IF (IC.EQ.9) GO TO 20                                             L  880
      IF (IC.EQ.IB) IE=IA                                               L  885
      WRITE (6,42)                                                      L  890
      WRITE (6,36) (IG,TIMD(IG),(DIST(IG,IH),IH=1,4),IG,IG=ID,IE)       L  895
   20 CONTINUE                                                          L  900
   21 CONTINUE                                                          L  905
      IF (L(14).EQ.0) GO TO 22                                          L  910
      WRITE (7,43) (TITLE(I),I=1,NTITL),(ATOM(2*I-1),ATOM(2*I),I=1,NI)  L  915
      VSIG=V(NVIR-1)*SIGB(25,1)                                         L  920
      IA=NVIR+3                                                         L  925
      ID=5                                                              L  930
      IE=6                                                              L  935
      IF (L(17).EQ.1) ID=2                                              L  940
      IF (L(16).EQ.1) ID=1                                              L  945
      IF (L(16).EQ.1) IE=4                                              L  950
      WRITE (7,44) ID,IE,NIT,NP3,IA                                     L  955
      WRITE (7,45) DTI,BUCKLE,EFFK,VSIG                                 L  960
C***  PUNCH INTERPOLATED DISTRIBUTIONS                                  L  965
      WRITE (7,46) (TINT(IB),IB=1,NIT)                                  L  970
      WRITE (7,46) ((DINT(IB,IC),IB=1,NIT),IC=ID,IE)                    L  975
   22 CONTINUE                                                          L  980
      RETURN                                                            L  985
C***                                                                    L  990
C***                                                                    L  995
   23 FORMAT ('1',35X,'TABLE OF MOMENTS OF DISTRIBUTIONS',/,41X,'(UNITS  L 1000
     1ARE MICROSECONDS)')                                               L 1005
   24 FORMAT ('0',//,10X,'NEUTRON DENSITY AT ',1PE10.3,' EV.',12X,'SLOWI L 1010
     1NG DOWN DENSITY AT ',1PE10.3,' EV.',///,'   N      CALC.          AS L 1015
     2YM.       T.C.      ERROR   N      CALC.        ASYM.       T.C.   L 1020
     3  ERROR',//)                                                      L 1025
   25 FORMAT (2(I4,1P2E13.4,1PE11.2,2PF8.3))                            L 1030
   26 FORMAT ('0','RSD',1P2E13.4,2PF19.3,1PE17.4,1PE13.4,2PF19.3)       L 1035
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27 FORMAT ('0',////,5X,'CALC. = CALCULATED FROM DISTRIBUTION AND CORR   L 1040
  1ECTED FOR TRUNCATION ERROR',/,5X,'ASYM. = ERIKSSON''S ASYMPTOTIC M   L 1045
  2OMENTS',/,5X,'T.C.  = TRUNCATION CORRECTION',/,5X,'ERROR = PERCENT   L 1050
  3 DEVIATION OF CALCULATED FROM ASYMPTOTIC',/,5X,'RSD   = RELATIVE S   L 1055
  4TANDARD DEVIATION')                                                  L 1060
28 FORMAT ('0',/////,' **** RATIO OF COMPUTED TO EXACT MOMENTS OF DEN   L 1065
  1SITY',///,14X,'N     CORMOM/EXM ',////)                              L 1070
29 FORMAT (I15,F15.8)                                                   L 1075
30 FORMAT ('0',///,19X,'ABSORBING STATE MOMENTS',31X,'TRUNCATION CORR   L 1080
  1ECTIONS',//,'     N     FISSION      LEAKAGE      CAPTURE        TOTA   L 1085
  2L          FISSION     LEAKAGE     CAPTURE      TOTAL',//)           L 1090
31 FORMAT ('0',I4,1P4E13.4,1PE15.4,1P3E11.4)                            L 1095
32 FORMAT ('0',/,'  RSD',1P4E13.4)                                      L 1100
33 FORMAT ('1',////,20X,'INTERPOLATED DISTRIBUTIONS',/,22X,'DTI =',1P   L 1105
  1E9.1,' SECONDS',///,13X,'N        TIME       DENSITY        S.D.D.   L 1110
  2   N',//)                                                            L 1115
34 FORMAT (' ',I14,1PE13.3,1PE12.3,1PE13.3,I7)                          L 1120
35 FORMAT ('1',////,25X,'INTERPOLATED DISTRIBUTIONS',/,27X,'DTI=',1PE   L 1125
  19.1,' SECONDS',///,'     N        TIME       FISSION      LEAKAGE     L 1130
  2  CAPTURE       TOTAL          N',//)                                L 1135
36 FORMAT (' ',I4,1P5E13.3,I7)                                          L 1140
37 FORMAT ('1',////,18X,'BROAD GROUP FLUXES',///,'    N       ENERGY R   L 1145
  1ANGE       CORE FLUX     SURFACE FLUX',//)                           L 1150
38 FORMAT ('     1    1.05E 07--',1PE8.2,1P2E14.4)                      L 1155
39 FORMAT ('0',I3,1PE12.2,'--',1PE8.2,1P2E14.4)                         L 1160
40 FORMAT ('1',////,21X,'DETAILED DISTRIBUTIONS',///,13X,'N        TIM   L 1165
  1E       DENSITY        S.D.D.       N',//)                          L 1170
41 FORMAT (' ',I14,1PE13.3,1PE12.3,1PE13.3,I7)                          L 1175
42 FORMAT ('1',////,27X,'DETAILED DISTRIBUTIONS',///'    N       TIME   L 1180
  1      FISSION      LEAKAGE      CAPTURE       TOTAL          N',//)   L 1185
  2                                                                     L 1190
43 FORMAT (18A4)                                                        L 1195
44 FORMAT (6I10)                                                        L 1200
45 FORMAT (5E16.8)                                                      L 1205
46 FORMAT (5E16.8)                                                      L 1210
47 FORMAT ('1',///,22X,'---- A MODS CALCULATON ----',///)               L 1215
48 FORMAT (18A4)                                                        L 1220
49 FORMAT ('0',/,13X,' THE MULTIPLICATION CONSTANT OF THE SYSTEM IS',   L 1225
  1/,27X,'**********************',/,27X,'* K =',E13.6,' *',/,27X,'*****   L 1230
  2***************')                                                    L 1235
50 FORMAT ('0',/,' THE CENTRAL CORE FLUX-AVERAGED ENERGY IS',1PE10.3,   L 1240
  1' EV.',/,' THE LEAKAGE FLUX-AVERAGED ENERGY IS      ',1PE10.3,' EV.   L 1245
  2')                                                                   L 1250
51 FORMAT ('0',' AT',1PE10.3,' SECONDS--',/,2PF11.3,' PERCENT OF THE    L 1255
  1NEUTRONS HAVE SUFFERED NON-FISSION CAPTURE, ',/,2PF11.3,' PERCENT    L 1260
  2OF THE NEUTRONS HAVE LEAKED FROM THE SYSTEM,       ',/,2PF11.3,' P   L 1265
  3ERCENT OF THE NEUTRONS HAVE CAUSED FISSION,',/,2PF11.3,' PERCENT O   L 1270
  4F THE NEUTRONS HAVE ENERGY BELOW',1PE9.2,' EV,',/,2PF11.3,' PERCEN   L 1275
  5T ARE STILL SLOWING DOWN,      ',/,2PF11.3,' PERCENT ARE LOST FROM   L 1280
  6THE SYSTEM, AND    ',/,2PF11.3,' PERCENT HAVE BEEN BYPASSED BY THE   L 1285
  7ARRAY. ')                                                            L 1290
52 FORMAT ('0',' ESTIMATE OF K FROM TRUNCATED DISTRIBUTION----',F       L 1295
  111.6)                                                                L 1300
53 FORMAT ('////,10X,'**** FINAL STATE VECTOR',/)                       L 1305
54 FORMAT (1P10E11.3)                                                   L 1310
55 FORMAT ('////,10X,'**** FINAL CORE FLUX VECTOR',/)                   L 1315
56 FORMAT ('////,10X,'**** FINAL SURFACE FLUX VECTOR',/)                L 1320
   END                                                                  L 1325
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      SUBROUTINE PARAM                                                  N     5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RF(2C0),G(  N    10
     1711),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5) N    15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(40C),SOENS(4  N    20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(2C1),E(  N    25
     42C1),DE(201),FII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2  N    30
     5(204),FVAR3(204),FVAR4(204)                                       N    35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2  N    40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21  N    45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),  N    50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTR(26,5),SIGFB(26,5),SIGNB(26,5),SI  N    55
     4GCB(26,5),SIGCB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI  N    60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDR  N    65
     6(2),RSDX(2)                                                       N    70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,FSTK,I,I  N    75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N  N    80
     2A,ND,NGR,NF,NI,NIT,NM,NMC,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT  N    85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE       N    90
      REAL LEAK,NORM                                                    N    95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6  N   100
     1)                                                                 N   105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(32C1),TINT)  N   110
     1, (FISS,DIST)                                                     N   115
C***                                                                    N   120
C***  THIS SUBROUTINE DEFINES ALL PARAMETERS OF THE STATE STRUCTURE AND  N   125
C***  ARRANGEMENT NOT PREVIOUSLY DEFINED.                               N   130
C***                                                                    N   135
      ZA=SQRT(3.204/1.674663E-12)                                       N   140
      V(1)=ZA*SQRT(E(1))                                                N   145
C***  TEST TO SEE WHICH OF U AND DU HAVE BEEN DEFINED                   N   150
      IF (DU(2).EQ.0.) GO TO 2                                          N   155
      U(1)=0.                                                           N   160
C***  THE NEXT EIGHT STATEMENTS DEFINE STATE BOUNDARIES WHEN THE        N   165
C***  LETHARGY INTERVALS DU ARE DEFINED IN INPUT DATA (TO LOG BASE 10).  N   170
C***  LETHARGY IS CONVERTED TO BASE E.                                  N   175
      DO 1 I=2,NVIR                                                     N   180
      DU(I)=2.3025851*DU(I)                                             N   185
      U(I)=U(I-1)+DU(I)                                                 N   190
      E(I)=E(1)*EXP(-U(I))                                              N   195
      V(I)=ZA*SQRT(E(I))                                                N   200
      DV(I)=V(I-1)-V(I)                                                 N   205
    1 DE(I)=E(I-1)-E(I)                                                 N   210
      GO TO 4                                                           N   215
C***  THE NEXT SEVEN STATEMENTS DEFINE STATE BOUNDARIES WHEN THE        N   220
C***  LETHARGIES U HAVE BEEN DEFINED.                                   N   225
    2 DO 3 I=2,NVIR                                                     N   230
      U(I)=U(I)*2.3025851                                               N   235
      E(I)=E(1)*EXP(-U(I))                                              N   240
      V(I)=ZA*SQRT(E(I))                                                N   245
      DU(I)=U(I)-U(I-1)                                                 N   250
      DV(I)=V(I-1)-V(I)                                                 N   255
    3 DE(I)=E(I-1)-E(I)                                                 N   260
    4 CONTINUE                                                          N   265
C***  IN THE ROUTINE BELOW THE LOCATION OF STATES WITHIN BROAD GROUPS IS N   270
C***  SPECIFIED BY NG.  IF NG(I)=0 STATE I SPANS THE BOUNDARY OF A BROAD N   275
C***  GROUP.  NNG(I) SPECIFIES THE INDEX OF THE LOWEST ENERGY STATE THAT N   280
C***  LIES COMPLETELY IN I.                                             N   285
      ID=1                                                              N   290
      NNG(1)=0                                                          N   295
      DO 6 IA=2,NVIR                                                    N   300
      DO 5 IB=ID,NGR                                                    N   305
      IF (EABN(IB).GE.E(IA-1)) GO TO 5                                  N   310
      NG(IA)=IB                                                         N   315
      IF (EABN(IB).GT.E(IA)) NG(IA)=0                                   N   320
      NNG(IB)=IA-1                                                      N   325
      ID=IB                                                             N   330
      GO TO 6                                                           N   335
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    5 CONTINUE                                                              M   340
    6 ID=IE                                                                 M   345
      IF (NNG(1).EQ.0) NNG(1)=1                                             M   350
      NG(1)=1                                                               M   355
      IF (NG(2).EQ.0) NG(1)=NG(3)-1                                         M   360
      IF (NG(2).NE.0) NG(1)=NG(2)                                           M   365
      RETURN                                                                M   370
      END                                                                   M   375


                  **** READ (*****

      SUBROUTINE READ (*)                                                   N     5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G(    N    10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)    N    15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SDENS(4    N    20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(    N    25
     42C1),DE(201),SII(201),VII(201),ANUNCR(71),NG(201),EVAR1(204),EVAR2    N    30
     5(204),EVAR3(204),EVAR4(204)                                           N    35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGE(26),BGSE(2    N    40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21    N    45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),    N    50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI    N    55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTRT(26),SI    N    60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDR    N    65
     6(2),RSDX(2)                                                           N    70
      COMMON ACCUM,BUCKLE,CONFR,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,I     N    75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N    N    80
     2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT    N    85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE          N    90
      REAL LEAK,NORM                                                        N    95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6    N   100
     1)                                                                     N   105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(32C1),TINT)    N   110
     1, (FISS,DIST)                                                         N   115
      COMMON NUMI(5),NUM2(5),NCMAX                                          N   120
      INTEGER NUM2*4                                                        N   125
      DIMENSION NOLIST(5)                                                   N   130
      DATA INIL/4H    /                                                     N   135
C***  NOLIST(I)=EXTERNAL FILE INDEX NUMBER FOR DATA SET FOR I-TH            N   140
C***  ISOTOPE IN THE SET DEFINED FOR THE PROBLEM BEING EXECUTED.            N   145
C***                                                                        N   150
C***                                                                        N   155
      NAMELIST /NUMBRS/ N,NVIR,NI,NF,NSCAT,NMO,NMOM,MAXT,CRIT,OPCRIT,SQC    N   160
     1RIT,SCRIT,CONVC,TIMWID,TIM,PTP,AMASS,RHO,BUCKLE,U,DU,E,SIGTB,SIGFB    N   165
     2,SIGNB,SIGCB,SIGEB,AMUB,H,SCALE,RSS                                   N   170
C***                                                                        N   175
C***  THE FOLLOWING VARIABLES DEFINE THE COMMON BLOCK SIZE AND MUST BE       N   180
C***  ADJUSTED WITH CHANGES IN COMMON.                                      N   185
C***  ND = MAXIMUM NUMBER OF ISOTOPES THAT CAN BE STORED IN THE COMMON      N   190
C***       BLOCK.                                                           N   195
C***  NOMAX = NUMBER OF ISOTOPES IN DATA FILE                               N   200
      ND=5                                                                  N   205
      NOMAX=43                                                              N   210
      MAXT=400                                                              N   215
      MAXR=74                                                               N   220
      MAXV=204                                                              N   225
      NGR=26                                                                N   230
      NTITLE=54                                                             N   235
C***  DU(2) = 0 SELECTS A DEFAULT OPTION IN PARAM WHEN U IS READ AS INPU     N   240
      DU(2)=0.                                                              N   245
C***  DEFAULT VALUES OF MISCELLANEOUS PARAMETERS.                           N   250
      IB=2*ND                                                               N   255
      DO 1 IA=1,IB                                                          N   260
    1 ATOM(IA)=INIL                                                         N   265
      N=MAXR-3                                                              N   270
      NVIR=N                                                                N   275
```

```
      NSCAT=1                                                           N  290
      NMO=2                                                             N  295
      NMOM(1)=1                                                         N  300
      NMOM(2)=2                                                         N  305
      CRIT=.001                                                         N  310
      OPCRIT=.4                                                         N  315
      SQCRIT=.2                                                         N  320
      SCRIT=.001                                                        N  325
      CONVC=0.00C01                                                     N  330
      TIMWID=0.                                                         N  335
      TIM(1)=0.                                                         N  340
      DO 2 IA=1,MAXV                                                    N  345
    2 PIP(IA)=0.                                                        N  350
      BUCKLF=0.                                                         N  355
      F(1)=1.05EC7                                                      N  360
      DL(1)=0.                                                          N  365
      DV(1)=0.                                                          N  370
      DU(1)=0.                                                          N  375
C***  DEFAULT VALUES OF MICROSCOPIC CROSS SECTIONS AND SCALE FACTORS.   N  380
      DO 3 IA=1,ND                                                      N  385
      DO 3 IB=1,NGR                                                     N  390
      SIGTR(IB,IA)=0.                                                   N  395
      SIGFB(IB,IA)=0.                                                   N  400
      SIGNB(IB,IA)=0.                                                   N  405
      SIGCR(IB,IA)=0.                                                   N  410
      SIGEB(IB,IA)=0.                                                   N  415
    3 AMUB(IB,IA)=0.                                                    N  420
      DO 4 IA=1,NGR                                                     N  425
      BGE(IA)=0.                                                        N  430
      BGSE(IA)=0.                                                       N  435
      DO 4 IB=1,ND                                                      N  440
    4 SCALE(IA,IB)=1.                                                   N  445
C***  DEFAULT VALUE OF RESONANCE SELF-SHIELDING COEFFICIENTS.           N  450
      DO 5 IA=1,ND                                                      N  455
      DO 5 IB=1,4                                                       N  460
      DO 5 IC=1,6                                                       N  465
      DO 5 ID=1,NGR                                                     N  470
    5 RSS(ID,IC,IB,IA)=1.                                               N  475
      LASTNO=0                                                          N  480
      REWIND 1                                                          N  485
      DO 6 IA=1,ND                                                      N  490
    6 NOLIST(IA)=0                                                      N  495
      READ (5,37,END=30) (TITLE(IA),IA=1,NTITLE)                        N  500
      READ (5,35) (L(IA),IA=1,30)                                       N  505
C***  L(2) IS USED TO CHECK FOR CONSISTENCY IN THE DATA SET             N  510
      IF (L(2).NE.1) WRITE (6,36)                                       N  515
      IF (L(2).NE.1) GO TO 30                                           N  520
      READ (5,32) (NOLIST(IA),IA=1,ND)                                  N  525
C***  NAMELIST NUMBRS MAY BE USED TO OVERRIDE CROSS SECTIONS READ FROM  N  530
C***  EXTERNAL FILES.  IF NOLIST(1)=0 THE EXTERNAL FILES ARE NOT READ.  N  535
      IF (NOLIST(1).EQ.0) GO TO 16                                      N  540
      DO 7 IA=1,ND                                                      N  545
      IF (NOLIST(IA).GT.NUMAX) GO TO 15                                 N  550
      IF (NOLIST(IA).EQ.0) GO TO 8                                      N  555
    7 CONTINUE                                                          N  560
      GO TO 9                                                           N  565
    8 NI=IA-1                                                           N  570
    9 CONTINUE                                                          N  575
C***  ISOTOPE NUMBERS ARE SEQUENCED NUMERICALLY EXCEPT THAT HYDROGEN    N  580
C***  (ISOTOPE 1) MUST APPEAR AT THE END OF THE LIST.                   N  585
      DO 10 IA=1,NI                                                     N  590
   10 NNG(IA)=NOLIST(IA)                                                N  595
C***  NNG TEMPORARILY PRESERVES INPUT ORDERING OF ISOTOPE LIST.         N  600
      IF (NI.EQ.1) GO TO 13                                             N  605
      IC=NI-1                                                           N  610
      DO 11 IA=1,IC                                                     N  615
      ID=NI-IA                                                          N  620
      DO 11 IB=1,ID                                                     N  625
      IF (NOLIST(IB+1).GT.NOLIST(IB)) GO TO 11                          N  630
```

```
      IE=NOLIST(IB)                                                     N  635
      NOLIST(IB)=NOLIST(IB+1)                                           N  640
      NOLIST(IB+1)=IE                                                   N  645
   11 CONTINUE                                                          N  650
      IF (NOLIST(1).NE.1) GO TO 13                                      N  655
C***  PUT HYDROGEN AT END OF LIST                                       N  660
      DO 12 IA=1,IC                                                     N  665
   12 NOLIST(IA)=NOLIST(IA+1)                                           N  670
      NOLIST(NI)=1                                                      N  675
   13 CONTINUE                                                          N  680
      DO 14 IA=1,NI                                                     N  685
      NC=IA                                                             N  690
   14 CALL GETIT (NOLIST(IA),NC,LASTNO)                                 N  695
      GO TO 16                                                          N  700
   15 WRITE (6,33)                                                      N  705
      GO TO 30                                                          N  710
   16 CONTINUE                                                          N  715
C***  IN NAMELIST FILE 'NUMBRS' POSITIVE MOMENTS MUST BE LISTED FIRST   N  720
C***  FOR VARIABLE 'NMOM' BEGINNING WITH NMOM=1,2...                    N  725
      READ (5,NUMBRS)                                                  N  730
C***  DENSITIES AND SCALE FACTORS ARE RE-ORDERED TO CONFORM TO PROPER   N  735
C***  ISOTOPE SEQUENCE.                                                 N  740
      IF (NI.EQ.1) GO TO 20                                             N  745
      IE=NI-1                                                           N  750
      DO 19 IA=1,IE                                                     N  755
      IF (NOLIST(IA).EQ.NNG(IA)) GO TO 19                               N  760
      ID=IA+1                                                           N  765
      DO 18 IB=ID,NI                                                    N  770
      IF (NOLIST(IA).NE.NNG(IB)) GO TO 18                               N  775
      ZA=RHO(IB)                                                        N  780
      RHO(IB)=RHO(IA)                                                   N  785
      RHO(IA)=ZA                                                        N  790
      IG=NNG(IB)                                                        N  795
      NNG(IB)=NNG(IA)                                                   N  800
      NNG(IA)=IG                                                        N  805
      DO 17 IC=1,NGR                                                    N  810
      ZA=SCALE(IC,IB)                                                   N  815
      SCALE(IC,IB)=SCALE(IC,IA)                                         N  820
   17 SCALE(IC,IA)=ZA                                                   N  825
      GO TO 19                                                          N  830
   18 CONTINUE                                                          N  835
   19 CONTINUE                                                          N  840
   20 CONTINUE                                                          N  845
C***  PARAMETER AND VECTOR INITIALIZATIONS FOLLOW                       N  850
      RR(NVIR)=0.                                                       N  855
      DU(NVIR)=1.E06                                                    N  860
      LL=1                                                              N  865
      NM=N-1                                                            N  870
      NP1=N+1                                                           N  875
      NP2=N+2                                                           N  880
      NP3=N+3                                                           N  885
      DO 21 IA=1,N                                                      N  890
   21 NG(IA)=0                                                          N  895
      IPEAK=2                                                           N  900
      NTIME=1                                                           N  905
      NTOP=0                                                            N  910
      NT=0                                                              N  915
      NVM=NVIR-1                                                        N  920
      SUMPOP=0.                                                         N  925
C***  THE ENERGY STRUCTURE OF THE MULTIGROUP CROSS SECTIONS IS DEFINED.  N  930
C***  THIS PROGRAM ASSUMES THE STRUCTURE OF THE RUSSIAN ABN SET.        N  935
      EABN(1)=6.5E06                                                    N  940
      EABN(2)=4.0E06                                                    N  945
      EABN(3)=2.5E06                                                    N  950
      EABN(4)=1.4E06                                                    N  955
      EABN(5)=8.0E05                                                    N  960
      EABN(6)=4.0E05                                                    N  965
      EABN(7)=2.0E05                                                    N  970
      EABN(8)=1.0E05                                                    N  975
      EABN(9)=4.65E04                                                   N  980
```

```
      DO 22 IA=II,NGR                                                   N  990
   22 EABN(IA)=EABN(IA-3)/10.                                           N  995
      EABN(26)=0.0252                                                   N 1000
      DEABN(1)=10.5E06-EABN(1)                                          N 1005
      IB=NGR-1                                                          N 1010
      DO 23 IA=2,IB                                                     N 1015
   23 DEABN(IA)=EABN(IA-1)-EABN(IA)                                     N 1020
      DEABN(NGR)=EABN(IB)                                               N 1025
      DO 24 IA=1,MAXT                                                   N 1030
   24 FISS(IA)=0.                                                       N 1035
      DO 25 IA=1,NVM                                                    N 1040
      VII(IA)=0.                                                        N 1045
      CII(IA)=0.                                                        N 1050
      RR(IA)=0.                                                         N 1055
      SFLUX(IA)=0.                                                      N 1060
   25 FLUX(IA)=0.                                                       N 1065
      CII(NVIR)=0.                                                      N 1070
      VII(NVIR)=0.                                                      N 1075
      DO 26 IA=1,MAXT                                                   N 1080
      DO 26 IB=1,6                                                      N 1085
   26 DIST(IA,IB)=0.                                                    N 1090
      CCCLNO=0.                                                         N 1095
      DO 28 IA=1,21                                                     N 1100
      DT(IA)=0.                                                         N 1105
      DO 27 IB=1,6                                                      N 1110
      AMOM(IA,IB)=0.                                                    N 1115
   27 CORMOM(IA,IB)=0.                                                  N 1120
      DO 28 IB=1,2                                                      N 1125
      EXM(IA,IB)=0.                                                     N 1130
   28 ERR(IA,IB)=0.                                                     N 1135
C***  THE SCATTERING PARAMETER ALPHA IS DEFINED FOR EACH ISOTOPE        N 1140
      DO 29 IA=1,NI                                                     N 1145
   29 ALPHA(IA)=((AMASS(IA)-1.)/(AMASS(IA)+1.))**2                      N 1150
      RETURN                                                            N 1155
   30 RETURN 1                                                          N 1160
C***                                                                    N 1165
C***                                                                    N 1170
   32 FORMAT (5I5)                                                      N 1175
   33 FORMAT ('1','**** INPUT DATA ERROR - REQUESTED ISOTOPE NOT IN EXTE N 1180
     1RNAL FILE - EXECUTION TERMINATED. ****')                          N 1185
   35 FORMAT (30I2)                                                     N 1190
   36 FORMAT ('1','*****  INPUT DATA ERROR.  EXECUTION TERMINATED*****') N 1195
     1                                                                  N 1200
   37 FORMAT (18A4)                                                     N 1205
      END                                                               N 1210
```

**** SQUARE ****

```
      SUBROUTINE SQUARE                                                 C   5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G(  C  10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGS(71,5),AMU(71,5)  C  15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SOURCS(4  C  20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(  C  25
     4201),DE(201),FII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2  C  30
     5(204),FVAR3(204),FVAR4(204)                                       C  35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2  C  40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21  C  45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RFO(5),  C  50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI  C  55
     4GCB(26,5),SIGSB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI  C  60
     5GSP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDR  C  65
     6(2),PSDX(2)                                                       C  70
      COMMON ACCUM,BUCKLE,CCENTR,CONVC,CRIT,CSENER,DDT,DTI,EEEK,ESTK,I,I  C  75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N  C  80
     2A,ND,NGR,NF,NI,NIT,NM,NMC,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT  C  85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE        C  90
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      REAL LEAK,NORM                                                    C   95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6  C  100
     1)                                                                 C  105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT)  C  110
     1, (FISS,DIST)                                                     C  115
C***                                                                    C  120
C***  SQUARES THE TRANSITION PROBABILITY MATRIX.                        C  125
C***  NEWLY SQUARED MATRIX ELEMENTS ARE INITIALLY STORED IN TRANSPOSED  C  130
C***  ORDER IN LOWER TRIANGLE OF MATRIX.                                C  135
C***                                                                    C  140
      CALL CANCEL (2)                                                   C  145
      IF (JROW.GE.NM) GO TO 7                                           C  150
C***  SQUARING ROUTINE WHEN SOME ROWS ARE NOT YET DEFINED.              C  155
C***  ITERATE ON ROWS                                                   C  160
      DO 6 IA=I,JROW                                                    C  165
      IC=IA+1                                                           C  170
C***  ITERATE ON COLUMNS                                                C  175
      DO 4 IB=ID,NP3                                                    C  180
      IF (IB.GT.JROW) GO TO 2                                           C  185
      DO 1 IC=IA,IB                                                     C  190
    1 P(IB,IA)=P(IB,IA)+P(IA,IC)*P(IC,IB)                               C  195
      GO TO 4                                                           C  200
    2 DO 3 IC=IA,JROW                                                   C  205
    3 P(IB,IA)=P(IB,IA)+P(IA,IC)*P(IC,IB)                               C  210
    4 CONTINUE                                                          C  215
      DO 5 IB=KROW,NP3                                                  C  220
C***  NEUTRONS WHICH HAVE ALREADY SCATTERED BEYOND JROW REMAIN IN THE    C  225
C***  SAME STATE UNTIL ITS ROW IS DEFINED.                              C  230
    5 P(IB,IA)=P(IB,IA)+P(IA,IB)                                        C  235
    6 P(IA,IA)=P(IA,IA)*P(IA,IA)                                        C  240
      GO TO 10                                                          C  245
C***  SQUARING ROUTINE WHEN ALL ROWS ARE DEFINED.                       C  250
    7 DO 9 IA=1,NM                                                      C  255
      IC=IA+1                                                           C  260
      DO 8 IB=ID,NP3                                                    C  265
      DO 8 IC=IA,IB                                                     C  270
    8 P(IB,IA)=P(IB,IA)+P(IA,IC)*P(IC,IB)                               C  275
    9 P(IA,IA)=P(IA,IA)*P(IA,IA)                                        C  280
C***  TRANSPOSE ELEMENTS FOR ALL DEFINED ROWS.                          C  285
   10 DO 11 IA=1,JROW                                                   C  290
      IC=IA+1                                                           C  295
      DO 11 IB=ID,NP3                                                   C  300
      P(IA,IB)=P(IB,IA)                                                 C  305
   11 P(IB,IA)=0.                                                       C  310
      RETURN                                                            C  315
      END                                                               C  320
```


**** STAWID ****

```
      SUBROUTINE STAWID (*)                                             P    5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G(  P   10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)  P   15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SCENS(4  P   20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),F(  P   25
     4201),DE(201),EII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2  P   30
     5(204),FVAR3(204),FVAR4(204)                                       P   35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2  P   40
     16),CORMOM(21,6),DCABN(26),DT(21),ECABN(26),EMIN(5),ERR(21,2),EXM(21  P   45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHOM(5),R(6),RHO(5),  P   50
     3RI(4),RSS(26,6,4,5),SAFG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI  P   55
     4GCB(26,5),SIGSB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI  P   60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDR  P   65
     6(2),RSDX(2)                                                       P   70
      COMMON ACCUM,BUCKLE,CCENSR,CONVC,CRIT,CSENEP,DDT,DTI,EFFK,ESTK,I,I  P   75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N  P   80
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```
      REAL LEAK,NORM                                                    P   95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6P  100
     1)                                                                 P  105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT)P  110
     1, (FISS,DIST)                                                     P  115
C***                                                                    P  120
C***  STAWID DETERMINES AN OPTIMIZED STATE WIDTH FOR THE FIRST ISOTOPE  P  125
C***  AND THE SPECIFIED VALUE OF NSCAT. STATE BOUNDARIES ARE REDEFINED  P  130
C***  USING THE OPTIMIZED LETHARGY WIDTH.  EQUATION NUMBERS ARE FOR     P  135
C***  CORRESPONDING EQUATIONS IN REFERENCE CITED IN CONTROL PROGRAM.    P  140
C***                                                                    P  145
      DOUBLE PRECISION ZAD,ZBD,ZCD,ZDD,ZED                              P  150
      C=0.                                                              P  155
C***  THE USE OF SCALE(25,1) IN THE FOLLOWING EXPRESSION (EQ. 41) IS    P  160
C***  ARBITRARY SINCE IN NORMAL USE THE DEFAULT OPTION SCALE(25,1)=1    P  165
C***  WILL BE EMPLOYED                                                  P  170
      ALPHAX=(1.-(1.-ALPHA(1))/SCALE(25,1))                             P  175
      ZB=NSCAT                                                          P  180
C***  THE NEXT STATEMENT COMPUTES A FIRST ORDER ESTIMATE OF THE LETHARGYP  185
C***  WIDTH OF A STATE (NOTE - LETHARGY IS DEFINED TO BASE 10 HERE)     P  190
      DU(1)=ALOG10(1./ALPHA(1))/(ZB+.5)                                 P  195
      DU(2)=DU(1)                                                       P  200
      ZA=0.                                                             P  205
      DO 1 IA=1,NI                                                      P  210
    1 ZA=ZA+SIGTB(25,IA)*RHO(IA)/AMASS(IA)                              P  215
      DO 2 IA=1,NI                                                      P  220
C***  EQUATION A2                                                       P  225
    2 C=C+((SCALE(25,IA)**2)/(1.-ALPHA(IA)))*(SIGEB(25,IA)*RHO(IA)/AMASSP  230
     1(IA))                                                             P  235
      C=C/ZA                                                            P  240
      NCOUNT=0                                                          P  245
C***  AN IMPLIED DO LOOP BEGINS HERE                                    P  250
    3 U(1)=0.                                                           P  255
      NCOUNT=NCOUNT+1                                                   P  260
      IF (NCOUNT.EQ.1) WRITE (6,14) DU(2),NSCAT,CONVC                   P  265
      IA=2+NSCAT                                                        P  270
      ZE=DU(2)*2.30259                                                  P  275
      DO 4 IB=2,IA                                                      P  280
      U(IB)=U(IB-1)+ZE                                                  P  285
    4 E(IB)=EXP(-U(IB))                                                 P  290
      ZAD=1./E(2)                                                       P  295
      ZBD=DLOG(ZAD)                                                     P  300
      ZCD=1./(ZAD-1.)                                                   P  305
C***  EQUATION A4                                                       P  310
      RR(2)=(ZAD**C-ZAD)/((ZAD-1.)*(C-1.))                              P  315
C***  EQUATION A5                                                       P  320
      EII(2)=(C*(ZAD**(C-1.)-1.))/((C-1.)*(ZAD**C-1.))                  P  325
C***  EQUATION A 10                                                     P  330
      EMIN(1)=E(2)*((1.-(C*((ALPHAX*ZAD)**2)*(ZAD**(C-2.)-1.))/((C-2.)*(P  335
     1ZAD**C-1.)))/(1.-(ALPHAX*ZAD*C*(ZAD**(C-1.)-1.))/((C-1.)*(ZAD**C-1P  340
     2.)))-1.)                                                          P  345
C***  THE NEXT THREE STATEMENTS COMPUTE THE ERROR IN THE CURRENT        P  350
C***  ESTIMATE OF DU AS REFLECTED IN THE FRACTIONAL DEVIATION OF EMIN   P  355
C***  FROM THE LOWEST STATE BOUNDARY                                    P  360
      ERRE=(EMIN(1)-E(2+NSCAT))/E(2+NSCAT)                              P  365
      ABERRE=ABS(ERRE)                                                  P  370
      CORRE=(2.*ZB*ERRE*E(2+NSCAT))/(2.*ZB+1.)                          P  375
C***  A NEW ESTIMATE OF DU IS CALCULATED, WRITTEN, AND TESTED FOR       P  380
C***  CONVERGENCE                                                       P  385
      DU(2)=-ALOG10((E(2+NSCAT)+CORRE)/E(2))/ZB                         P  390
      WRITE (6,15) NCOUNT,ERRE,RR(2),DU(2)                              P  395
      IF (ABERRE.LT.CONVC) GO TO 6                                      P  400
      IB=2+NSCAT                                                        P  405
      DO 5 IA=3,IB                                                      P  410
    5 DU(IA)=DU(2)                                                      P  415
      IF (NCOUNT.LT.21) GO TO 3                                         P  420
      WRITE (6,16)                                                      P  425
C***  IF CONVERGENCE HAS NOT BEEN ACHIEVED AFTER 21 ITERATIONS EXECUTION P  430
C***  TERMINATES.                                                       P  435
      GO TO 13                                                          P  440
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```
    6 IF (L(4).EQ.0) GO TO 9                                                P  445
C***  THE NEXT EIGHT STATEMENTS DEFINE THE STATE STRUCTURE FROM F(NVM)        P  450
C***  UPWARD IF L(4)=1.                                                       P  455
      ID=NVIR-2                                                             P  460
      DO 7 IA=3,ID                                                          P  465
    7 DU(IA)=DU(2)                                                          P  470
      DU(NVM)=DU(2)                                                         P  475
      U(NVM)=0.                                                             P  480
      DO 8 IA=2,NVM                                                         P  485
    8 U(NVM)=U(NVM)+DU(IA)                                                  P  490
      F(1)=E(NVM)*10.**U(NVM)                                               P  495
      GO TO 12                                                              P  500
C***  THE NEXT FIVE STATEMENTS DEFINE THE STATE STRUCTURE FROM E(1)         P  505
C***  DOWNWARD (DEFAULT OPTION).                                            P  510
    9 DO 10 IA=3,NVM                                                        P  515
   10 DU(IA)=DU(2)                                                          P  520
      U(NVM)=0.                                                             P  525
      DO 11 IA=2,NVM                                                        P  530
   11 U(NVM)=U(NVM)+DU(IA)                                                  P  535
   12 CONTINUE                                                              P  540
C***                                                                        P  545
      RETURN                                                                P  550
   13 RETURN 1                                                              P  555
C***                                                                        P  560
C***                                                                        P  565
   14 FORMAT ('1',////,20X,'STATE WIDTH OPTIMIZATION DATA',///,10X,'THE     P  570
     1INITIAL LETHARGY DECREMENT (LOG10) IS',E12.5,//,10X,I1,' STATE(S)     P  575
     2PER SCATTERING INTERVAL',//,10X,'THE CONVERGENCE CRITERIA IS',E9.5     P  580
     3)                                                                     P  585
   15 FORMAT ('0',//,' AT ITERATION NUMBER',I3,', THE ERROR IS',E9.5,',     P  590
     1RR(2) = ',F8.5,', AND THE NEW LETHARGY WIDTH IS',E12.5)               P  595
   16 FORMAT ('0','****CONVERGENCE HAS NOT BEEN ATTAINED.  EXECUTION TER    P  600
     1MINATED****')                                                         P  605
      END                                                                   P  610
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**** TRAN ****

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      SUBROUTINE TRAN                                                       GGG    5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(2C0),G(    GGG   10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)    GGG   15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SCENS(4    GGG   20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(2C1),E(    GGG   25
     4201),DE(201),VII(201),VII(201),ANUMCR(71),NG(201),FVAR1(2C4),FVAR2    GGG   30
     5(2C4),FVAR3(204),FVAR4(204)                                           GGG   35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGF(26),BGSF(2    GGG   40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21    GGG   45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHC(5),    GGG   50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI    GGG   55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTBT(26),SI    GGG   60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSC(6),RSCR    GGG   65
     6(2),RSDX(2)                                                           GGG   70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,I    GGG   75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N    GGG   80
     2A,ND,NGR,NF,NI,NIT,NM,NMC,NP1,NP2,NP3,NSCAT,NT,NTIMS,NTITLE,NTM,NT    GGG   85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE          GGG   90
      REAL LEAK,NORM                                                        GGG   95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6    GGG  100
     1)                                                                     GGG  105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(2201),TINT)    GGG  110
     1, (FISS,DIST)                                                         GGG  115
C***                                                                        GGG  120
C***  TRAN COMPUTES THE TRANSFER COEFFICIENT MATRIX WITH THE ASSUMPTION     GGG  125
C***  OF CONSTANT CROSS SECTIONS ACROSS EACH STATE.  THE ARRAY OF TRANS     GGG  130
C***  FER COEFFICIENTS IS COMPUTED IN TRANSPOSED FORM SO IT MAY BE          GGG  135
C***  STORED IN THE LOWER TRIANGULAR PORTION OF THE REAL MATRIX.  THE       GGG  140
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C***
      DOUBLE PRECISION ZAD,ZBD,ZCD,ZDD,ZFD                                  160
      DIMENSION UB(26), DUB(26)                                             165
C***  LETHARGIES OF BROAD GROUP BOUNDARIES AND LETHARGY WIDTHS OF BROAD      170
C***  GROUPS ARE DEFINED FOR USE IN LETHARGY WEIGHTING OF INELASTIC          175
C***  CROSS SECTIONS                                                        180
      UB(1)=ALOG(E(1)/EABN(1))                                              185
      DUB(1)=UB(1)                                                          190
      DO 1 IA=2,NGR                                                         195
      UB(IA)=ALOG(E(1)/EABN(IA))                                            200
    1 DUB(IA)=UB(IA)-UB(IA-1)                                               205
C***  NII= NUMBER OF NON-HYDROGENOUS ISOTOPES.                              210
      NII=NI                                                                215
      ZX=E(N+NTOP)                                                          220
      E(N+NTOP)=0.                                                          225
      IF (AMASS(NI).EQ.1.) NII=NI-1                                         230
      RR(1)=1.                                                              235
C***  INITIALIZE THE MATRIX                                                 240
      DO 2 IA=1,NP3                                                         245
      DO 2 IB=1,NP3                                                         250
    2 P(IA,IB)=0.                                                           255
C***  STATE 1 IS A DELTA FUNCTION AND IS POPULATED ONLY WHEN CURRENTLY      260
C***  BEING USED AS A SOURCE STATE (N1=1).                                  265
      N1=2                                                                  270
      IF (NTOP.EQ.0.AND.L(11).EQ.1) N1=1                                    275
      DO 39 IA=N1,NM                                                        280
C***  IA IS THE ROW INDEX ON THE REAL MATRIX.                               285
C***  IAP IS THE ROW INDEX ON THE VIRTUAL MATRIX.                           290
      IAP=IA+NTOP                                                           295
      NAG=NG(IAP)                                                           300
      IF (NAG.EQ.0) NAG=NG(IAP-1)                                           305
      C=0.                                                                  310
      DO 3 IC=1,NI                                                          315
C***  FIRST FACTOR ON RIGHT SIDE OF EQ. 36.                                 320
      SIGEP(IC)=SIGE(IA,IC)*(SCALE(NAG,IC)**2)/(1.-ALPHA(IC))               325
      C=C+SIGEP(IC)                                                         330
C***  EQ. 41                                                                335
      ALP(IC)=(1.-(1.-ALPHA(IC))/SCALE(NAG,IC))                             340
    3 EMIN(IC)=ALP(IC)                                                      345
      IF (IA.EQ.1) GO TO 8                                                  350
C***  AVERGES FOR STATES 2 TO NM                                            355
      ZAD=E(IAP-1)/E(IAP)                                                   360
      ZBD=DLOG(ZAD)                                                         365
      ZCD=1./(ZAD-1.)                                                       370
      IF (NII.EQ.0) GO TO 4                                                 375
C***  EQ. A4                                                                380
      RR(IAP)=(ZAD**C-ZAD)/((ZAD-1.)*(C-1.))                               385
C***  EQ. A5                                                                390
      EII(IAP)=(E(IAP-1)*C*(ZAD**(C-1.)-1.))/((C-1.)*(ZAD**C-1.))           395
      GO TO 5                                                               400
C***  EQS. A4 AND A5 MODIFIED FOR PURE HYDROGEN.                            405
    4 RR(IAP)=(ZAD*ZBD)/(ZAD-1.)                                            410
      EII(IAP)=(E(IAP-1)*ZBD)/(ZAD-1.)                                      415
    5 CONTINUE                                                              420
      VI=1.                                                                 425
C***  EXPECTATION OF INVERSE VELOCITY AS IN TABLE III                       430
      DO 7 IB=2,6                                                           435
      ZDD=0.                                                                440
      ID=IB-1                                                               445
      DO 6 IC=1,ID                                                          450
      ZFD=IC+1                                                              455
    6 ZDD=ZDD+((ZBD/2.)**IC)/DGAMMA(ZFD)                                    460
    7 VI=VI+((2.*C)**(IB-1))*(1.-(1./(ZAD**.5-1.))*ZDD)                     465
      VI=(VI*2.)/(RR(IAP)*(V(IAP-1)+V(IAP)))                               470
      GO TO 9                                                               475
    8 EII(1+NTOP)=E(1+NTOP)                                                 480
      VI=1./V(1+NTOP)                                                       485
C***  VII(IAP) IS EFFECTIVELY THE MEAN VELOCITY OF NEUTRONS IN STATE IAP    490
    9 VII(IAP)=1./VI                                                        495
                                                                            500
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C***   EQ. B1.                                                          GGGGGGG  505
       G(IA)=SIGT(IA)*VII(IAP)                                          GGGGGGG  510
       IF (IA.EQ.1) GO TO 14                                            GGGGGGG  515
       IF (NII.EQ.0) GO TO 11                                           GGGGGGG  520
       DO 10 IB=1,NII                                                   GGGGGGG  525
C***   EQ. A12.  ALAM = N SUB S,K.                                      GGGGGGG  530
       ALAM(IB)=(((C-1.)*(ZAD**C-1.))/(C*(ZAD**C-ZAD))-ALP(IB))/(1.-ALP(I GGGGGGG  535
      1B))                                                              GGGGGGG  540
C***   EQ. A10                                                          GGGGGGG  545
    10 EMIN(IB)=E(IAP)*((1.-(C*((ALP(IB)*ZAD)**2)*(ZAD**(C-2.)-1.))/((C-2 GGGGGGG  550
      1.)*(ZAD**C-1.)))/(1.-(ALP(IB)*ZAD*C*(ZAD**(C-1.)-1.))/((C-1.)*(ZAD GGGGGGG  555
      2**C-1.)))-1.)                                                    GGGGGGG  560
    11 CONTINUE                                                         GGGGGGG  565
C***   IF THE LAST ISOTOPE (NI) IS HYDROGEN--                           GGGGGGG  570
       IF (NI.NE.NII) ALAM(NI)=E(IAP)/EII(IAP)                          GGGGGGG  575
       IF (NI.NE.NII) EMIN(NI)=0.                                       GGGGGGG  580
       ID=IA+1                                                          GGGGGGG  585
       DO 13 IC=1,NI                                                    GGGGGGG  590
C***   FIRST FACTOR IN EQ. A11                                          GGGGGGG  595
       HS=(SCALE(NAG,IC)*ALAM(IC))/(E(IAP)-EMIN(IC))                    GGGGGGG  600
       DO 12 IB=IC,N                                                    GGGGGGG  605
       IBP=IB+NTOP                                                      GGGGGGG  610
C***   EQ A11D AND SECOND TERM OF EQ. 37                                GGGGGGG  615
       IF (EMIN(IC).LT.E(IBP)) P(IB,IA)=P(IB,IA)+SIGE(IA,IC)*HS*DE(IBP) GGGGGGG  620
C***   EQ A11C                                                          GGGGGGG  625
       IF (EMIN(IC).GT.E(IBP-1)) GO TO 13                               GGGGGGG  630
C***   EQ A11B AND SECOND TERM OF EQ. 37                                GGGGGGG  635
       IF (EMIN(IC).GE.E(IBP)) P(IB,IA)=P(IB,IA)+SIGE(IA,IC)*HS*(E(IBP-1) GGGGGGG  640
      1-EMIN(IC))                                                       GGGGGGG  645
    12 CONTINUE                                                         GGGGGGG  650
    13 CONTINUE                                                         GGGGGGG  655
       GO TO 18                                                         GGGGGGG  660
    14 CONTINUE                                                         GGGGGGG  665
C***   SPECIAL ROUTINE FOR ROW 1.                                       GGGGGGG  670
       DO 15 IC=1,NI                                                    GGGGGGG  675
    15 EMIN(IC)=EMIN(IC)*EII(NTOP+1)                                    GGGGGGG  680
       ID=IA+1                                                          GGGGGGG  685
       DO 17 IC=1,NI                                                    GGGGGGG  690
       DO 16 IB=ID,N                                                    GGGGGGG  695
       IBP=IB+NTOP                                                      GGGGGGG  700
C***   EQS. 39                                                          GGGGGGG  705
       IF (EMIN(IC).LT.E(IBP)) P(IB,1)=P(IB,1)+(SIGEP(IC)*DE(IBP))/EII(NT GGGGGGG  710
      1OP+1)                                                            GGGGGGG  715
       IF (EMIN(IC).GT.E(IBP-1)) GO TO 17                               GGGGGGG  720
       IF (EMIN(IC).GE.E(IBP)) P(IB,1)=P(IB,1)+(SIGEP(IC)*(E(IBP-1)-EMIN( GGGGGGG  725
      1IC)))/EII(NTOP+1)                                                GGGGGGG  730
    16 CONTINUE                                                         GGGGGGG  735
    17 CONTINUE                                                         GGGGGGG  740
    18 CONTINUE                                                         GGGGGGG  745
       IF (L(12).EQ.0) GO TO 36                                         GGGGGGG  750
C***   THE FOLLOWING ROUTINE, TERMINATING AT STATEMENT NUMBER 35,       GGGGGGG  755
C***   COMPUTES INELASTIC SCATTERING CONTRIBUTIONS TO THE TRANSFER      GGGGGGG  760
C***   COEFFICIENTS.  THE COMPLEXITY OF THE ROUTINE ARISES FROM THE     GGGGGGG  765
C***   NEED TO DISTRIBUTE BROAD GROUP INELASTIC TRANSFER PROBABILITIES  GGGGGGG  770
C***   OVER MANY STATES WHOSE BOUNDARIES WILL GENERALLY NOT BE ALIGNED  GGGGGGG  775
C***   (THAT IS, COINCIDENT) WITH BROAD GROUP BOUNDARIES.  THE WISE     GGGGGGG  780
C***   USER WILL TAKE THE CORRECTNESS OF THE FOLLOWING ON FAITH, AND    GGGGGGG  785
C***   NOT ATTEMPT TO VERIFY IT.                                        GGGGGGG  790
C***                                                                    GGGGGGG  795
C***   IF THE ROW IAP LIES BELOW THE INELASTIC THRESHOLD BYPASS WHAT     GGGGGGG  800
C***   FOLLOWS.  INELASTIC SCATTERING FROM ROW 1 OF THE VIRTUAL MATRIX  GGGGGGG  805
C***   IS NOT ALLOWED.  THUS IF A DELTA FUNCTION SOURCE IS DESIRED WHEN GGGGGGG  810
C***   INELASTIC SCATTERING IS PRESENT IT SHOULD BE DEFINED IN STATE 2  GGGGGGG  815
C***   BY READING THE VECTOR  PTP(2)=1. IN NAMELIST FILE 'NUMBRS'.      GGGGGGG  820
       IF (IAP.GT.NNG(11).OR.IA.EQ.1) GO TO 36                          GGGGGGG  825
C***   IAJ IS THE BROAD GROUP INDEX OF STATE IAP.                       GGGGGGG  830
       IAJ=NG(IAP)                                                      GGGGGGG  835
       IAJ1=IAJ+1                                                       GGGGGGG  840
       ID=IA+1                                                          GGGGGGG  845
C***   ROW 12 AND COLUMN 12 OF HARRAY MUST CONTAIN ZEROES.              GGGGGGG  850
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      DO 19 IB=1,12                                                     C  860
   19 H(IB,12,IC)=0.                                                    C  865
      DO 20 IB=1,12                                                     C  870
   20 H(12,IB,IC)=0.                                                    C  875
   21 CONTINUE                                                          C  880
C***  STATEMENTS THROUGH 28 ARE EXECUTED IF STATE IAP STRADDLES A       C  885
C***  BROAD GROUP BOUNDARY.                                            C  890
      IF (IAJ.NE.0) GO TO 29                                            C  895
      IAJ=NG(IAP-1)                                                     C  900
      IAJ1=IAJ+1                                                        C  905
      W1=(E(IAP-1)-EABN(IAJ))/(DE(IAP)*SIGT(IA))                        C  910
      W2=(EABN(IAJ)-E(IAP))/(DE(IAP)*SIGT(IA))                          C  915
C***  DIAGONAL MATRIX ELEMENT ON GROUP BOUNDARY.                        C  920
      DO 22 IC=1,NI                                                     C  925
   22 P(IA,IA)=P(IA,IA)+SIGNB(IAJ,IC)*W1*(H(IAJ,IAJ,IC)+H(IAJ,IAJ+1,IC)*C  930
     1((U(IAP)-UB(IAJ))/DUB(IAJ+1)))+SIGNB(IAJ+1,IC)*H(IAJ+1,IAJ+1,IC)*(C  935
     2(EABN(IAJ)-E(IAP))/DE(IAP))/SIGT(IA)                              C  940
C***  TEMPORARY RENORMALIZATION. SEE STATEMENT ---(111).                C  945
      P(IA,IA)=P(IA,IA)/(1.-E(IAP)/EII(IAP))                            C  950
      IE=NNG(NG(IAP+1))-NTOP                                            C  955
C***  IE IS THE REAL INDEX OF THE LOWEST STATE IN GROUP IAJ NOT ON      C  960
C***  THE GROUP BOUNDARY.                                              C  965
      DO 23 IB=ID,IE                                                    C  970
      IBP=IB+NTOP                                                       C  975
      ZE=W1*DU(IBP)/DUB(IAJ1)                                           C  980
      DO 23 IC=1,NI                                                     C  985
   23 P(IB,IA)=P(IB,IA)+ZE*SIGNB(IAJ,IC)*H(IAJ,IAJ1,IC)                 C  990
C***  INELASTIC TRANSFER TO THE STATE LYING ON THE LOWER BOUNDARY OF IAJ C  995
      DO 24 IC=1,NI                                                     C 1000
   24 P(IE+1,IA)=P(IE+1,IA)-W2*SIGNB(IAJ1,IC)*H(IAJ1,IAJ+2,IC)*(UB(IAJ1)C 1005
     1-U(IE+1+NTOP))/DUB(IAJ+2)-W1*SIGNB(IAJ,IC)*(H(IAJ,IAJ1,IC)*(U(IE+NC 1010
     2TOP)-UB(IAJ1))/DUB(IAJ1)+H(IAJ,IAJ+2,IC)*(UB(IAJ1)-U(IE+1+NTOP))/DC 1015
     3UB(IAJ+2))                                                        C 1020
C***  INELASTIC TRANSFER OUT OF GROUP IAJ TO STATES NOT LYING ON GROUP  C 1025
C***  BOUNDARIES.                                                      C 1030
      IF (IAP.GE.NNG(10)) GO TO 36                                      C 1035
      IE=IE+2                                                           C 1040
      IG=NNG(II)-NTOP+1                                                 C 1045
      DO 28 IB=IE,IG                                                    C 1050
      IBP=IB+NTOP                                                       C 1055
      IBJ=NG(IBP)                                                       C 1060
      IF (IBJ.EQ.0) GO TO 26                                            C 1065
      ZE=DU(IBP)/DUB(IBJ)                                               C 1070
      DO 25 IC=1,NI                                                     C 1075
   25 P(IB,IA)=P(IB,IA)+ZE*(W1*SIGNB(IAJ,IC)*H(IAJ,IBJ,IC)+W2*SIGNB(IAJ1C 1080
     1,IC)*H(IAJ1,IBJ,IC))                                              C 1085
      GO TO 28                                                          C 1090
   26 IBJ=NG(IBP+1)                                                     C 1095
C***  INELASTIC TRANSFER OUT OF GROUP IAJ TO STATES ON GROUP BOUNDARIES C 1100
      W3=-(U(IBP-1)-UB(IBJ-1))/DUB(IBJ-1)                               C 1105
      W4=-(UB(IBJ-1)-U(IBP))/DUB(IBJ)                                   C 1110
      DO 27 IC=1,NI                                                     C 1115
   27 P(IB,IA)=P(IB,IA)+W1*SIGNB(IAJ,IC)*(W3*H(IAJ,IBJ-1,IC)+W4*H(IAJ,IBC 1120
     1J,IC))+W2*SIGNB(IAJ1,IC)*(W3*H(IAJ1,IBJ-1,IC)+W4*H(IAJ1,IBJ,IC))  C 1125
   28 CONTINUE                                                          C 1130
      GO TO 36                                                          C 1135
C***  STATEMENTS THROUGH  36  ARE EXECUTED IF STATE IAP DOES NOT LIE    C 1140
C***  ON A GROUP BOUNDARY.                                             C 1145
   29 CONTINUE                                                          C 1150
      DO 30 IC=1,NI                                                     C 1155
C***  IF FINAL STATE LIES IN SAME GROUP AS STATE IAP DOWNSCATTER IS     C 1160
C***  IGNORED FOR LACK OF A REASONABLE PREDICTOR.                       C 1165
   30 P(IA,IA)=P(IA,IA)+SIGN(IA,IC)*H(IAJ,IAJ,IC)                       C 1170
      P(IA,IA)=P(IA,IA)/(1.-E(IAP)/EII(IAP))                            C 1175
      IE=NNG(NG(IAP))-NTOP+1                                            C 1180
      ZE=-(UB(IAJ)-U(IE+NTOP))/DUB(IAJ1)                                C 1185
      DO 31 IC=1,NI                                                     C 1190
C***  FINAL STATE(IE) LIES ON BOUNDARY OF GROUP NG(IAP).                C 1195
   31 P(IE,IA)=P(IE,IA)+SIGN(IA,IC)*H(IAJ,IAJ1,IC)*ZE                   C 1200
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```
C***  FINAL STATE DOES NOT LIE ON A GROUP BOUNDARY.                    C 1205
      IF (IAP.GT.NNG(10)) GO TO 36                                     C 1210
      IE=IE+1                                                          C 1215
      IG=NNG(11)-NTOP+1                                                C 1220
      DO 35 IB=IE,IG                                                   C 1225
C***  FINAL STATE LIES ON A GROUP BOUNDARY.                            C 1230
      IBP=IB+NTOP                                                      C 1235
      IBJ=NG(IBP)                                                      C 1240
      IF (IBJ.EQ.0) GO TO 33                                           C 1245
      ZE=DU(IBP)/DUB(IBJ)                                              C 1250
      DO 32 IC=1,NI                                                    C 1255
   32 P(IB,IA)=P(IB,IA)+SIGN(IA,IC)*H(IAJ,IBJ,IC)*ZE                   C 1260
      GO TO 35                                                         C 1265
   33 IBJ=NG(IB+NTOP+1)                                                C 1270
      IBJM=IBJ-1                                                       C 1275
      W3=-(U(IBP-1)-UB(IBJM))/DUB(IBJM)                                C 1280
      W4=-(UB(IBJM)-U(IBP))/DUB(IBJ)                                   C 1285
      DO 34 IC=1,NI                                                    C 1290
   34 P(IB,IA)=P(IB,IA)+SIGN(IA,IC)*(H(IAJ,IBJM,IC)*W3+H(IAJ,IBJ,IC)*W4) C 1295
   35 CONTINUE                                                         C 1300
C***  END OF INELASTIC SCATTERING ROUTINE.                             C 1305
   36 CONTINUE                                                         C 1310
C***  COEFFICIENTS FOR TRANSFER TO ABSORBING STATES                    C 1315
      DO 37 IC=1,NI                                                    C 1320
      P(IA,IA)=P(IA,IA)+SIGP(IC)                                       C 1325
   37 P(NP1,IA)=P(NP1,IA)+SIGC(IA,IC)                                  C 1330
      P(NP2,IA)=DB2(IA)                                                C 1335
      IF (NF.EQ.0) GO TO 39                                            C 1340
      DO 38 IC=1,NI                                                    C 1345
   38 P(NP3,IA)=P(NP3,IA)+SIGF(IA,IC)                                  C 1350
C***  NORMALIZE DIAGONAL ELEMENT.                                      C 1355
   39 P(IA,IA)=P(IA,IA)*(1.-E(IAP)/EII(IAP))                           C 1360
C***  DIAGONAL COEFFICIENTS FOR ABSORBING STATES.                      C 1365
      P(N,N)=1.                                                        C 1370
      P(NP1,NP1)=1.                                                    C 1375
      P(NP2,NP2)=1.                                                    C 1380
      P(NP3,NP3)=1.                                                    C 1385
      E(N+NTOP)=ZX                                                     C 1390
      RETURN                                                           C 1395
      END                                                              C 1400
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**** WRITE1 ****

```
      SUBROUTINE WRITE1                                                R     5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G(  R    10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)  R    15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SCENS(4  R    20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(  R    25
     4201),DE(201),EII(201),VII(201),ANUNOR(71),NG(201),EVAR1(204),EVAR2  R    30
     5(204),EVAR3(204),EVAR4(204)                                        R    35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGE(26),BGSE(2  R    40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21  R    45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),  R    50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNP(26,5),SI  R    55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTRT(26),SI  R    60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDP  R    65
     6(2),RSDX(2)                                                        R    70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESIK,I,I  R    75
     1A,IB,IC,ID,IF,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N  R    80
     2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT  R    85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE        R    90
      REAL LEAK,NORM                                                   R    95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6  R   100
     1)                                                                  R   105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT)  R   110
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C***   WRITE1 LISTS INPUT AND COMPUTED DATA FOR PROBLEM DESCRIPTION.          R  125
C***   IF VARIABLE ND IS REDEFINED TO EXCEED 5 THIS SUBROUTINE MUST          R  130
C***   BE MODIFIED                                                           R  135
C***                                                                         R  140
C***   ---- WRITE PROBLEM TITLE                                             R  145
      DO 1 ID=1,2                                                           R  150
      WRITE (6,8)                                                           R  155
      WRITE (6,9) (TITLE(I),I=1,NTITLE)                                     R  160
      WRITE (6,3) N,NVIR,NI,NF,CRIT,OPCRIT,SQCRIT                           R  165
      WRITE (6,11) (L(IA),IA=1,30)                                          R  170
      IF (L(6).EQ.1) WRITE (6,12) ATOM(1),ATOM(2)                           R  175
      WRITE (6,4)                                                           R  180
      WRITE (6,5) (ATOM(2*I-1),ATOM(2*I),AMASS(I),RHO(I),RHON(I),ALPHA(I    R  185
     1),I=1,NI)                                                             R  190
    1 WRITE (6,10) BUCKLE                                                   R  195
      WRITE (6,6)                                                           R  200
      WRITE (6,7) (IA,(SCALE(IA,IB),IB=1,5),IA=1,NGR)                       R  205
      WRITE (6,13) (ATOM(1),ATOM(2),I=1,5)                                  R  210
      IB=NG(NVIR-1)                                                         R  215
      IF (IB.EQ.0) IB=NG(NVIR-2)                                            R  220
      WRITE (6,14) (IA,SIGTBT(IA),SIGTBB(IA),DB2B(IA),SIGEB(IA,1),SIGCB(    R  225
     1IA,1),SIGNB(IA,1),SIGFB(IA,1),AMUB(IA,1),IA=1,IB)                     R  230
      IF (NI.EQ.1) GO TO 2                                                  R  235
      WRITE (6,15) (ATOM(3),ATOM(4),I=1,5),(ATOM(5),ATOM(6),I=1,5)          R  240
      WRITE (6,16) (IA,(SIGEB(IA,IC),SIGCB(IA,IC),SIGNB(IA,IC),SIGFB(IA,    R  245
     1IC),AMUB(IA,IC),IC=2,3),IA=1,IB)                                      R  250
      IF (NI.LT.4) GO TO 2                                                  R  255
      WRITE (6,15) (ATOM(7),ATOM(8),I=1,5),(ATOM(9),ATOM(10),I=1,5)         R  260
      WRITE (6,16) (IA,(SIGEB(IA,IC),SIGCB(IA,IC),SIGNB(IA,IC),SIGFB(IA,    R  265
     1IC),AMUB(IA,IC),IC=4,5),IA=1,IB)                                      R  270
    2 CONTINUE                                                              R  275
      RETURN                                                                R  280
C***                                                                        R  285
C***                                                                        R  290
    3 FORMAT ('0',//,15X,'NUMBER OF REAL TRANSIENT STATES      ',I8,/,15    R  295
     1X,'NUMBER OF VIRTUAL TRANSIENT STATES   ',I8,/,15X,'NUMBER OF SCAT    R  300
     2TTERING ISOTOPES      ',I8,/,15X,'NUMBER OF FISSILE ISOTOPES        R  305
     3      ',I8,/,15X,'ROW GENERATION CRITERION                ',F8.4,/,15 R  310
     4X,'ARRAY GENERATION CRITERION            ',F8.4,/,15X,'ARRAY SQUARI    R  315
     5NG CRITERION              ',F8.4)                                     R  320
    4 FORMAT ('0',///,24X,'----SYSTEM PARAMETERS----',//,9X,'ISOTOPE        R  325
     1 ATOMIC MASS  MASS DENSITY  NUCLEAR DENSITY   ALPHA',//)             R  330
    5 FORMAT (8X,2A4,F14.3,F13.4,F16.5,F12.4)                               R  335
    6 FORMAT ('1',//,29X,'-----TABLE OF SCALE FACTORS-----',//,18X,'GROUP   R  340
     1            ISOTOPIC INDEX',/,28X,'1       2       3       4        R  345
     2 5',/)                                                                R  350
    7 FORMAT (I22,5F8.2)                                                    R  355
    8 FORMAT ('1',///,'                                    *********       R  360
     1 ',/,'                                 * MOD-5 *          ',/,'      R  365
     2                                *********          ',/////)          R  370
    9 FORMAT (6X,18A4)                                                      R  375
   10 FORMAT ('0',///,'                SYSTEM BUCKLING =',F10.6,'/SC.CM.',/ R  380
     1)                                                                     R  385
   11 FORMAT ('0',/,' LOGICALS = ',6(5I2,1X),//)                            R  390
   12 FORMAT ('0',/,'     STATE WIDTH OPTIMIZED FOR THE ISOTOPE ',2A4)      R  395
   13 FORMAT ('1',35X,'-----MACROSCOPIC CROSS SECTIONS-----',///,' GROUP    R  400
     1',38X,5(A9,A4),/,'                  TOTAL      TRANSPORT       LEAKAGE R  405
     2  ELASTIC       CAPTURE     INELASTIC       FISSION       COSINE ',//) R  410
     3                                                                      R  415
   14 FORMAT (I4,F14.6,7E13.6)                                              R  420
   15 FORMAT ('1','GROUP',A7,A4,9(A7,A4),/,'              ELASTIC     CAPTURE R  425
     1  INELASTIC    FISSION      COSINE     ELASTIC     CAPTURE    INELASTIC R  430
     2    FISSION      COSINE',//)                                          R  435
   16 FORMAT (I5,10F11.5)                                                   R  440
      END                                                                   R  445
```

```
      SUBROUTINE WRITE2 (*)                                                  S      5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G(     S     10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)     S     15
     2,DB2(71),SIGTR(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SDENS(4     S     20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(     S     25
     4201),DE(201),EII(201),VII(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2     S     30
     5(204),FVAR3(204),FVAR4(204)                                           S     35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGE(26),BGSE(2     S     40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21     S     45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),     S     50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI     S     55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTRT(26),SI     S     60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSD(6),RSDR     S     65
     6(2),RSDX(2)                                                           S     70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DCT,DTI,EFFK,ESTK,I,I     S     75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N     S     80
     2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT     S     85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE          S     90
      REAL LEAK,NORM                                                        S     95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), DIST(400,6     S    100
     1)                                                                     S    105
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT)     S    110
     1, (FISS,DIST)                                                         S    115
C***                                                                        S    120
C***  WRITE2 LISTS STATE STRUCTURE PARAMETERS AND TESTS THE TRANSFER        S    125
C***  COEFFICIENT ARRAY FOR NUMERICAL CONSISTENCY.  THAT IS, ELEMENTS       S    130
C***  ON A ROW (COLUMN OF TRANSPOSED MATRIX HERE) MUST SUM TO UNITY.        S    135
C***                                                                        S    140
      IF (L(3).EQ.0) GO TO 1                                                S    145
C***  STATE PARAMETERS ARE LISTED WHEN BOTTOM STATES OF THE REAL AND        S    150
C***  VIRTUAL ARRAYS ARE COINCIDENT.                                        S    155
      WRITE (6,11)                                                          S    160
      WRITE (6,12) (IA,U(IA),DU(IA),E(IA),EII(IA),DE(IA),V(IA),VII(IA),D     S    165
     1V(IA),RR(IA),NG(IA),IA,IA=1,NVIR)                                     S    170
    1 CONTINUE                                                              S    175
C***  TEST ARRAY.  ACCEPTABLE TOLERANCE HAS BEEN SET ARBITRARILY AT         S    180
C***  + OR - 0.0001.                                                        S    185
      DO 2 IA=1,NP3                                                         S    190
      DO 2 IB=IA,NP3                                                        S    195
C***  P(1,IA) IS TEMPORARILY USED TO ACCUMULATE SUMS FOR MATRIX ROW IA.     S    200
    2 P(1,IA)=P(1,IA)+P(IB,IA)                                              S    205
      ID=2                                                                  S    210
      IF (L(1).EQ.1.AND.L(12).EQ.0.AND.L(2).EQ.1) ID=1                      S    215
      DO 3 IA=ID,NP3                                                        S    220
      IF (P(1,IA).GT.1.0001) GO TO 4                                        S    225
      IF (P(1,IA).LT.0.9999) GO TO 4                                        S    230
    3 CONTINUE                                                              S    235
      GO TO 5                                                               S    240
    4 ID=NTOP+1                                                             S    245
      WRITE (6,9) ID                                                        S    250
C***  IF ROW SUMS DO NOT LIE WITHIN STATED LIMITS THE PROBLEM IS            S    255
C***  TERMINATED.  EXCEPTION--IF(N,2N) REACTIONS OCCUR THE ROW SUMS ARE     S    260
C***  LISTED BUT EXECUTION IS ALLOWED TO CONTINUE                           S    265
      WRITE (6,10) (P(1,IA),IA=1,NP3)                                       S    270
      IF (L(19).EQ.1) GO TO 7                                               S    275
      GO TO 8                                                               S    280
    5 DO 6 IA=1,NP3                                                         S    285
    6 P(1,IA)=0.                                                            S    290
    7 RETURN                                                                S    295
    8 RETURN 1                                                              S    300
C***                                                                        S    305
    9 FORMAT ('1','-----TRANSFER COEFFICIENT ROW SUM CRITERIA IS NOT SAT     S    310
     1ISFIED-----','///,'  ROW SUMS, BEGINNING WITH ROW',I4,///)            S    315
   10 FORMAT (10F12.8)                                                      S    320
   11 FORMAT ('1',//,40X,'-----STATE PARAMETERS-----',///,' STATE       U     S    325
     1          DU          E          EII          DE          V          VI  S    330
     2I         DV          RR         NG  STATE',///)                      S    335
```

```
   12 FORMAT ('X',I4,1PE12.3,1P8E11.3,I5,I6)                                S  340
      END                                                                   S  345


                    **** XSECT  ****


      SUBROUTINE XSECT                                                      T    5
      COMMON P(74,74),POP(74,2),PTP(204),FLUX(200),SFLUX(200),RR(200),G(    T   10
     171),SIGT(71),SIGF(71,5),SIGN(71,5),SIGC(71,5),SIGE(71,5),AMU(71,5)    T   15
     2,DB2(71),SIGTP(71),FISS(400),LEAK(400),CAPT(400),TOTL(400),SCENS(4    T   20
     300),DENS(400),FLCOR(200),TIM(400),U(201),DU(201),V(201),DV(201),E(    T   25
     4201),DE(201),EIT(201),VIT(201),ANUNOR(71),NG(201),FVAR1(204),FVAR2    T   30
     5(204),FVAR3(204),FVAR4(204)                                           T   35
      COMMON ALP(5),ALPHA(5),AMASS(5),AMOM(21,6),ATOM(10),BGE(26),BGSE(2    T   40
     16),CORMOM(21,6),DEABN(26),DT(21),EABN(26),EMIN(5),ERR(21,2),EXM(21    T   45
     2,2),H(12,12,5),L(30),NMOM(21),NNG(26),NORM(6),RHON(5),R(6),RHO(5),    T   50
     3RI(4),RSS(26,6,4,5),SARG(5),SIGTB(26,5),SIGFB(26,5),SIGNB(26,5),SI    T   55
     4GCB(26,5),SIGEB(26,5),AMUB(26,5),DB2B(26),SIGTRB(26),SIGTRT(26),SI    T   60
     5GEP(5),SSTAR(5),SZERO(5),SCALE(26,5),TITLE(72),ALAM(5),RSC(6),RSCR    T   65
     6(2),RSDX(2)                                                           T   70
      COMMON ACCUM,BUCKLE,CCENER,CONVC,CRIT,CSENER,DDT,DTI,EFFK,ESTK,I,I    T   75
     1A,IB,IC,ID,IE,IG,IH,IND,IPEAK,J,JJ,JROW,KROW,LL,MAXR,MAXT,MAXV,N,N    T   80
     2A,ND,NGR,NF,NI,NIT,NM,NMO,NP1,NP2,NP3,NSCAT,NT,NTIME,NTITLE,NTM,NT    T   85
     3OP,NVIR,NVM,OPCRIT,SCRIT,SQCRIT,SUMPOP,TIMWID,ZA,ZB,ZC,ZD,ZE          T   90
      REAL LEAK,NORM                                                        T   95
      DIMENSION DTIM(400), TIMD(400), DINT(200,6), TINT(200), CIST(400,6    T  100
     1)                                                                     T  105
      DIMENSION N2N(5)                                                      T  110
      REAL N2N                                                              T  115
      EQUIVALENCE (P,DTIM), (P(401),TIMD), (P(801),DINT), (P(3201),TINT)    T  120
     1, (FISS,CIST)                                                         T  125
C***                                                                        T  130
C***  XSECT PERFORMS TWO MANIPULATIONS ON DATA. (1) MACROSCOPIC CROSS       T  135
C***  SECTIONS ARE DIVIDED BY THE TOTAL CROSS SECTION, (2) THE INELASTIC    T  140
C***  SCATTERING MATRIX IS TRANSPOSED AND NORMALIZED.                       T  145
C***                                                                        T  150
      DO 2 IA=1,NM                                                          T  155
      DO 1 IB=1,NI                                                          T  160
      ZA=1./SIGT(IA)                                                        T  165
      SIGC(IA,IB)=SIGC(IA,IB)*ZA                                            T  170
      SIGN(IA,IB)=SIGN(IA,IB)*ZA                                            T  175
      SIGF(IA,IB)=SIGF(IA,IB)*ZA                                            T  180
C***  THE P1 ANISOTROPY CORRECTION IS INCLUDED IN ELASTIC CROSS SECTIONS     T  185
    1 SIGE(IA,IB)=((1.+2./(3.*AMASS(IB))-AMU(IA,IB))*SIGE(IA,IB))*ZA        T  190
    2 DB2(IA)=DB2(IA)*ZA                                                    T  195
C***  IF THE INELASTIC ARRAY HAS BEEN NORMALIZED AND TRANSPOSED THE         T  200
C***  FOLLOWING IS BYPASSED.                                                T  205
      IF (L(2).EQ.0) GO TO 14                                               T  210
C***  IF THERE ARE NO INELASTIC CROSS SECTIONS IN THE DATA SET THE          T  215
C***  NORMALIZING ROUTINE IS BYPASSED.                                      T  220
C***  TEST FOR INELASTIC SCATTERING                                         T  225
      DO 3 IA=1,NI                                                          T  230
      DO 3 IB=1,26                                                          T  235
      IF (SIGNB(IB,IA).EQ.0.) GO TO 3                                       T  240
      L(12)=1                                                               T  245
      GO TO 4                                                               T  250
    3 CONTINUE                                                              T  255
    4 CONTINUE                                                              T  260
      IF (L(12).EQ.0) GO TO 14                                              T  265
C***  MICROSCOPIC TRANSFER CROSS SECTIONS ARE NORMALIZED TO UNIT ROW        T  270
C***  SUM BELOW.                                                            T  275
      DO 9 IA=1,NI                                                          T  280
C***  RATIO OF NUMBER OF NEUTRONS LEAVING AN INELASTIC SCATTERING           T  285
C***  REACTION TO NUMBER ENTERING IS EVALUATED.  (N,2N) REACTIONS ARE       T  290
C***  IMPORTANT ONLY IN GROUP 1.                                            T  295
      ANOR=0.                                                               T  300
      N2N(IA)=1.                                                            T  305
      DO 5 IC=1,12                                                          T  310
```

```
      5 ANOR=ANOR+H(1,IC,IA)                                                T  315
        ZB=SIGNB(1,IA)/RHON(IA)                                             T  320
        IF (ANOR.EQ.ZB) GO TO 6                                             T  325
        N2N(IA)=ANOR/ZB                                                     T  330
        L(19)=1                                                             T  335
        WRITE (6,15) ATOM(2*IA-1),ATOM(2*IA)                                T  340
      6 CONTINUE                                                            T  345
        DO 9 IB=1,12                                                        T  350
        ANOR=0.                                                             T  355
        DO 7 IC=1,12                                                        T  360
      7 ANOR=ANOR+H(IB,IC,IA)                                               T  365
        IF (ANOR.EQ.0.) GO TO 9                                             T  370
        ANOR=1./ANOR                                                        T  375
        DO 8 IC=1,12                                                        T  380
      8 H(IB,IC,IA)=ANOR*H(IB,IC,IA)                                        T  385
      9 CONTINUE                                                            T  390
C***  SHIFT ROWS OF H-ARRAY TO PLACE ELEMENTS IN PROPER POSITION FOR         T  395
C***  THIS PROGRAM.                                                         T  400
        DO 11 IA=1,NI                                                       T  405
        IE=0                                                                T  410
        DO 10 IB=2,12                                                       T  415
        IE=IE+1                                                             T  420
        DO 10 IC=IB,12                                                      T  425
        ID=12-IC+IB                                                         T  430
     10 H(IB,ID,IA)=H(IB,ID-IE,IA)                                          T  435
C***  SET LOWER TRIANGULAR PORTION OF H-ARRAY TO ZERO (FOR LOOKS ONLY).     T  440
        DO 11 IB=2,12                                                       T  445
        ID=IB-1                                                             T  450
        DO 11 IC=1,ID                                                       T  455
        H(IB,IC,IA)=0.                                                      T  460
     11 CONTINUE                                                            T  465
        DO 12 IA=1,NI                                                       T  470
        DO 12 IB=1,12                                                       T  475
     12 H(1,IB,IA)=N2N(IA)*H(1,IB,IA)                                       T  480
        WRITE (6,16)                                                        T  485
        DO 13 I=1,NI                                                        T  490
        WRITE (6,17) ATOM(2*I-1),ATOM(2*I),N2N(I)                           T  495
     13 WRITE (6,18) (IA,(H(IA,IB,I),IB=1,12),IA=1,12)                      T  500
     14 CONTINUE                                                            T  505
        RETURN                                                              T  510
C***                                                                        T  515
C***                                                                        T  520
     15 FORMAT ('0',' **** (N,2N) REACTIONS OCCUR IN ',2A4,'.  ROW SUM ERR   T  525
       1ORS WILL NOT STOP EXECUTION OF THIS PROBLEM')                       T  530
     16 FORMAT ('1',4X,'-----NORMALIZED TRANSFER COEFFICIENTS FOR INELASTI   T  535
       1C SCATTERING-----',////,34X,' H(I,J)',//,'  I  ',30X,'      J',/,'  T  540
       2        1        2        3        4        5        6        7     T  545
       3    10       11       12')                                         T  550
     17 FORMAT ('0',/,' -----',2A4,'-----',/,' NEUTRON YIELD FROM INELASTI   T  555
       1C SCATTERING IN GROUP I =',F5.2,/)                                  T  560
     18 FORMAT (I3,F9.3,11F7.3)                                             T  565
        END                                                                 T  570
```

APPENDIX G

SLOAD Listing with output

```
C                                  *********
C                                  * SLOAD *
C                                  *********
C
C***  PROGRAM FOR CREATING DATA FILE OF 26-GROUP CROSS SECTION SETS
      COMMON/BLOCK/NUM2,ATOM(2),AMASS,SIGTB(26),SIGFB(26),SIGNB(
     126),SIGCB(26),SIGEB(26),AMUB(26),H(12,12),RSS(26,6,4)
      DIMENSION DBLOCK(928),RS(26,24),NSIG(24),NTYP(24)
      DIMENSION DU(26)
      DIMENSION JBGW(26)
      INTEGER*4 NUM2
      EQUIVALENCE (NUM2,DBLOCK)
      DATA DU/3*.48,2*.57,3*.69,17*.77,0./
      MISC=43
      DO 100 IA=1,MISC
      NUM2=IA
      READ(5,402) DUMMY
      READ(5,401)AMASS
      READ(5,408) ATOM(1),ATOM(2)
  408 FORMAT(2A4)
  401 FORMAT(F10.3)
  402 FORMAT(4X,A4)
      WRITE(6,601)
  601 FORMAT(1H1)
      WRITE(6,602) IA, ATOM(1),ATOM(2),AMASS
  602 FORMAT(1HO,//,' CROSS SECTIONS FOR ISOTOPE NUMBER',I3,' =',2A4,' O
     1F ATOMIC MASS',F10.3,'.',////)
      READ(5,403)(SIGTB(I),SIGFB(I),SIGCB(I),SIGNB(I),SIGEB(I),AMUB(I),
     1I=1,26)
  403 FORMAT(4X,6F12.4)
      WRITE(6,603)
  603 FORMAT(1HO,////,'    I     DU        SIGT       SIGF       SIGC     SIGN
     1    SIG.      AMU    T',/,' ----------------------------------------
     2-------------------------------',//)
      WRITE(6,604)(I,DU(I),SIGTB(I),SIGFB(I),SIGCB(I),SIGNB(I),SIGEB(I),
     1AMUB(I),I=1,26)
  604 FORMAT(1HO,I4,F7.2,F10.2,F10.2,F11.3,F7.2,F9.2,F7.2,I5)
C***  INITIALIZE H ARRAY
      DO 80 IB=1,12
      DO 80 IC=1,12
   80 H(IB,IC)=0.
      READ(5,402)DUMMY
      READ(5,404)NP
  404 FORMAT(4X,I2)
      IF(NR.GT.12) NR=NP/10
      READ(5,405) ((H(IB,IC),IB=1,12),IC=1,NR)
  405 FORMAT(12F5.2)
      WRITE(6,601)
      WRITE(6,605)IA,ATOM(1),ATOM(2)
  605 FORMAT(1HO,///,' INELASTIC SCATTERING MATRIX FOR ISOTOPE NUMBER',I
     13,' -',2A4,'.',///,'      N      0      1      2      3      4      5
     2      6      7      8      9     10     11',//)
      WRITE (6,606)(IC,(H(IB,IC),IB=1,12),IC=1,12)
  606 FORMAT(1HO,I7,F8.2,11F6.2)
C***  INITIALIZE RSS TO DEFAULT VALUES
      DO 50 IB=1,26
      DO 50 IC=1,6
      DO 50 ID=1,4
   50 RSS(IB,IC,ID)=1.
      READ(5,402)DUMMY
      READ(5,406)NCOL,NROW,(NTYP(IB),NSIG(IB),IB=1,16)
  406 FORMAT(3I4,32I2)
      DO 518 IB=1,NROW
      READ(5,407)JBGW(IB),(RS(IB,IC),IC=1,NCOL)
  518 CONTINUE
  407 FORMAT(I5,15F5.2)
      DO 51 IB=1,NROW
```

```
      IF(NGIG(IB).*0.2) GO TO 60
   52 CONTINUE
C***  LINEAR INTERPOLATION ON F-VALUES IN COLUMN 2.
      DO 53 IB=1,4
      DO 53 IC=1,NROW
   53 RSS(JROW(IC),2,IB)=(RSS(JROW(IC), 1,IB)+RSS(JROW(IC),3,IB))/2.
   60 CONTINUE
C***  NOW PRINTER LISTS DATA AS RECEIVED
      WRITE(6,601)
      WRITE(6,607)IA,ATOM(1),ATOM(2)
  607 FORMAT(1H0,//,' RESONANCE SELF SHIELDING TABLE FOR ISOTOPE',I3,' -
     1',2A4,'.',///,' GROUP                FISSION                    CA
     2PTURE                TOTAL                 ELASTIC
     3',/,'      1     2     3     4     5     6     1     2     3     4
     4  5     6',/)
      WRITE(6,608)(IB,((RSS(IB,IC,ID),IC=1,6),ID=1,4),IB=1,26)
  608 FORMAT(1H0,I4,F6.2,23F5.2)
      WRITE(1,9999) CBLOCK
 9999 FORMAT(4(23A4))
  100 CONTINUE
      STOP
      END
```

```
C***  SAMPLE CROSS SECTION SET FOR INPUT TO SLOAD

 URANIUM-235
   235.
  U-235
    1        6.3000        1.7500        0.0200        1.0300        3.5000        0.8400
    2        7.4000        1.1500        0.0300        1.9200        4.3000        0.8000
    3        7.7000        1.2500        0.0400        1.9100        4.5000        0.7100
    4        7.0000        1.2800        0.0600        1.7600        3.9000        0.5500
    5        6.6000        1.2500        0.1200        1.3800        3.8500        0.4500
    6        7.4000        1.2300        0.1700        1.2000        4.8000        0.3500
    7        9.2000        1.4100        0.2500        1.0000        6.5400        0.2300
    8       11.2000        1.7000        0.4000        0.6000        8.5000        0.1300
    9       12.5000        2.1000        0.6000        0.1800        9.6200        0.0700
   10       14.0000        2.6500        1.0000       -0.0600       10.3000        0.0400
   11       16.0000        3.4000        1.5000        0.0000       11.1000        0.0200
   12       19.0000        4.4000        2.1000        0.0000       12.5000        0.0100
   13       23.0000        5.4000        2.7500        0.0000       14.8000        0.0027
   14       27.0000        7.3000        3.8000        0.0000       15.9000        0.0027
   15       32.0000       11.0000        6.3000        0.0000       14.7000        0.0027
   16       38.0000       16.0000        9.5000        0.0000       12.5000        0.0027
   17       47.7000       22.0000       13.5000       -0.0000       12.2000        0.0027
   18       69.0000       35.0000       22.0000        0.0000       12.0000        0.0027
   19       88.0000       45.0000       31.0000        0.0000       12.0000        0.0027
   20      111.0000       45.0000       54.0000        0.0000       12.0000        0.0027
   21       93.0000       37.0000       44.0000        0.0000       12.0000        0.0027
   22       39.0000       20.0000        7.0000        0.0000       12.0000        0.0027
   23       61.0000       35.0000       13.0000        0.0000       13.0000        0.0027
   24       88.0000       64.0000       10.0000        0.0000       14.0000        0.0027
   25      205.0000      155.0000       35.0000        0.0000       15.0000        0.0027
   26      698.0000      582.0000      101.0000       -0.0000       15.0000        0.0027
 URANIUM-235
ROW=10
   .00   .01   .05   .25   .43   .56   .35   .14   .04   .01
   .02   .08   .35   .54   .51   .26   .11   .04   .01
   .10   .27   .53   .54   .30   .12   .04   .01    .
   .20   .35   .57   .40   .16   .06   .02    .     .
   .26   .51   .37   .20   .08   .02    .     .     .
   .44   .44   .22   .08   .02    .     .     .     .
   .61   .38   .01    .     .     .     .     .     .
   .21   .29   .08   .02    .     .     .     .     .
```

.19 .07 .02 : : : : : :
.05 .01 : : : : : : :
0.235

14	13	1 5	1 4	1 3	1 1	2 5	2 4	2 3	2 1	3 4	3 3	3 1	4 4	4 3	4 1		
11	1.00	1.00	0.98	0.97	1.00	1.00	0.98	0.97	1.00	0.99	0.98	1.00	1.00	1.00			
12	1.00	0.99	0.96	0.94	1.00	0.99	0.96	0.94	1.00	0.98	0.96	1.00	1.00	0.99			
13	1.00	0.99	0.93	0.89	1.00	0.99	0.93	0.89	0.99	0.96	0.93	1.00	0.99	0.98			
14	1.00	0.97	0.88	0.82	1.00	0.97	0.88	0.82	0.96	0.92	0.88	1.00	0.98	0.96			
15	1.00	0.94	0.82	0.75	1.00	0.94	0.81	0.74	0.93	0.88	0.82	0.99	0.97	0.95			
16	0.99	0.90	0.75	0.67	0.99	0.89	0.74	0.65	0.85	0.78	0.73	1.00	1.00	1.00			
17	0.97	0.83	0.67	0.60	0.97	0.81	0.64	0.56	0.80	0.70	0.62	1.00	1.00	1.00			
18	0.95	0.77	0.61	0.55	0.94	0.74	0.56	0.48	0.70	0.56	0.50	1.00	1.00	1.00			
19	0.91	0.70	0.56	0.52	0.90	0.65	0.48	0.43	0.57	0.42	0.39	1.00	1.00	1.00			
20	0.88	0.64	0.52	0.49	0.86	0.58	0.42	0.38	0.42	0.36	0.32	1.00	1.00	1.00			
21	0.86	0.62	0.50	0.47	0.83	0.55	0.40	0.35	0.42	0.31	0.29	1.00	1.00	1.00			
22	1.00	0.90	0.79	0.74	0.97	0.81	0.62	0.56	0.82	0.68	0.64	1.00	1.00	1.00			
23	1.00	0.87	0.74	0.70	1.00	0.86	0.68	0.64	0.80	0.65	0.63	1.00	1.00	1.00			

CROSS SECTIONS FOR ISOTOPE NUMBER 34 - U-235 OF ATOMIC MASS 235.000.

I	DU	SIGT	SIGF	SIGC	SIGN	SIGE	AMU	I
1	0.48	6.30	1.75	0.020	1.03	3.50	0.84	1
2	0.48	7.40	1.15	0.030	1.92	4.30	0.80	2
3	0.48	7.70	1.25	0.040	1.91	4.50	0.71	3
4	0.57	7.00	1.28	0.060	1.76	3.90	0.55	4
5	0.57	6.60	1.25	0.120	1.38	3.85	0.45	5
6	0.69	7.40	1.23	0.170	1.20	4.80	0.35	6
7	0.69	9.20	1.41	0.250	1.00	6.54	0.23	7
8	0.69	11.20	1.70	0.400	0.60	8.50	0.13	8
9	0.77	12.50	2.10	0.600	0.18	9.62	0.07	9
10	0.77	14.00	2.65	1.000	0.06	10.30	0.04	10
11	0.77	16.00	3.40	1.500	0.0	11.10	0.02	11
12	0.77	19.00	4.40	2.100	0.0	12.50	0.01	12
13	0.77	23.00	5.40	2.750	0.0	14.80	0.00	13
14	0.77	27.00	7.30	3.800	0.0	15.90	0.00	14
15	0.77	32.00	11.00	6.300	0.0	14.70	0.00	15
16	0.77	38.00	16.00	9.500	0.0	12.50	0.00	16
17	0.77	47.70	22.00	13.500	0.0	12.20	0.00	17
18	0.77	69.00	35.00	22.000	0.0	12.00	0.00	18
19	0.77	88.00	45.00	31.000	0.0	12.00	0.00	19
20	0.77	111.00	45.00	54.000	0.0	12.00	0.00	20
21	0.77	93.00	37.00	44.000	0.0	12.00	0.00	21
22	0.77	39.00	20.00	7.000	0.0	12.00	0.00	22
23	0.77	61.00	35.00	13.000	0.0	13.00	0.00	23
24	0.77	88.00	64.00	10.000	0.0	14.00	0.00	24
25	0.77	205.00	155.00	35.000	0.0	15.00	0.00	25
26	0.0	698.00	582.00	101.000	0.0	15.00	0.00	26

RESONANCE SELF SHIELDING TABLE FOR ISOTOPE 34 - U-235 .

GROUP	FISSION						CAPTURE						TOTAL						ELASTIC					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	0.97	0.97	0.98	1.00	1.00	1.00	0.97	0.97	0.98	1.00	1.00	1.00	0.98	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	0.94	0.95	0.96	0.99	1.00	1.00	0.94	0.95	0.96	0.99	1.00	1.00	0.96	0.97	0.98	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00
13	0.89	0.91	0.93	0.99	1.00	1.00	0.89	0.91	0.93	0.99	1.00	1.00	0.93	0.94	0.96	0.99	1.00	1.00	0.98	0.98	0.99	1.00	1.00	1.00
14	0.82	0.85	0.88	0.97	1.00	1.00	0.82	0.85	0.88	0.97	1.00	1.00	0.88	0.90	0.92	0.96	1.00	1.00	0.96	0.97	0.98	1.00	1.00	1.00
15	0.75	0.78	0.82	0.94	1.00	1.00	0.74	0.77	0.81	0.94	1.00	1.00	0.82	0.85	0.88	0.93	1.00	1.00	0.95	0.96	0.97	0.99	1.00	1.00
16	0.67	0.71	0.75	0.90	0.99	1.00	0.65	0.69	0.74	0.89	0.99	1.00	0.73	0.75	0.78	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17	0.60	0.63	0.67	0.83	0.97	1.00	0.56	0.60	0.64	0.81	0.97	1.00	0.62	0.66	0.70	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18	0.55	0.58	0.61	0.77	0.95	1.00	0.48	0.52	0.56	0.74	0.94	1.00	0.50	0.53	0.56	0.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19	0.52	0.54	0.56	0.70	0.91	1.00	0.43	0.45	0.48	0.65	0.90	1.00	0.39	0.40	0.42	0.57	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	0.49	0.50	0.52	0.64	0.88	1.00	0.38	0.40	0.42	0.58	0.86	1.00	0.32	0.34	0.36	0.42	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	0.47	0.48	0.50	0.62	0.86	1.00	0.35	0.37	0.40	0.55	0.83	1.00	0.29	0.30	0.31	0.42	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
22	0.74	0.76	0.79	0.90	1.00	1.00	0.56	0.59	0.62	0.81	0.97	1.00	0.64	0.66	0.68	0.82	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
23	0.70	0.72	0.74	0.87	1.00	1.00	0.64	0.66	0.68	0.86	1.00	1.00	0.63	0.64	0.65	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

INELASTIC SCATTERING MATRIX FOR ISOTOPE NUMBER 34 - U-235 .

N	0	1	2	3	4	5	6	7	8	9	10	11
1	0.0	0.01	0.05	0.25	0.43	0.56	0.35	0.14	0.04	0.01	0.0	0.0
2	0.02	0.08	0.35	0.54	0.51	0.26	0.11	0.04	0.01	0.0	0.0	0.0
3	0.10	0.27	0.53	0.54	0.30	0.12	0.04	0.01	0.0	0.0	0.0	0.0
4	0.20	0.35	0.57	0.40	0.16	0.06	0.02	0.0	0.0	0.0	0.0	0.0
5	0.20	0.51	0.37	0.20	0.08	0.02	0.0	0.0	0.0	0.0	0.0	0.0
6	0.44	0.44	0.22	0.08	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.61	0.38	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.21	0.29	0.08	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.09	0.07	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.05	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX H

EXAMPLES OF OUTPUT FROM MOD-5

Note: The listings that follow are incomplete and are intended only to provide verification that the sample data decks have been properly executed.

STATE WIDTH OPTIMIZATION DATA

THE INITIAL LETHARGY DECREMENT (LOG10) IS 0.96645E-01
1 STATE(S) PER SCATTERING INTERVAL
THE CONVERGENCE CRITERIA IS 0.00001

AT ITERATION NUMBER 1, THE ERROR IS -0.02748, RR(2) = 1.49646, AND THE NEW LETHARGY WIDTH IS 0.10468E 00

AT ITERATION NUMBER 2, THE ERROR IS -0.00554, RR(2) = 1.54896, AND THE NEW LETHARGY WIDTH IS 0.10628E 00

AT ITERATION NUMBER 3, THE ERROR IS -0.00116, RR(2) = 1.55972, AND THE NEW LETHARGY WIDTH IS 0.10662E 00

AT ITERATION NUMBER 4, THE ERROR IS -0.00025, RR(2) = 1.56198, AND THE NEW LETHARGY WIDTH IS 0.10669E 00

AT ITERATION NUMBER 5, THE ERROR IS -0.00005, RR(2) = 1.56246, AND THE NEW LETHARGY WIDTH IS 0.10671E 00

AT ITERATION NUMBER 6, THE ERROR IS -0.00001, RR(2) = 1.56256, AND THE NEW LETHARGY WIDTH IS 0.10671E 00

AT ITERATION NUMBER 7, THE ERROR IS -0.00000, RR(2) = 1.56258, AND THE NEW LETHARGY WIDTH IS 0.10671E 00

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*********
* MOD-5 *
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EXAMPLE NUMBER 1
EVALUATION OF ASYMPTOTIC SOLUTION TO SLOWING DOWN EQUATION.
INFINITE GRAPHITE MODERATOR. DELTA SOURCE IN TIME AND ENERGY.

NUMBER OF REAL TRANSIENT STATES	51
NUMBER OF VIRTUAL TRANSIENT STATES	51
NUMBER OF SCATTTERING ISOTOPES	1
NUMBER OF FISSILE ISOTOPES	0
ROW GENERATION CRITERION	0.0010
ARRAY GENERATION CRITERION	0.4000
ARRAY SQUARING CRITERION	0.2000

LOGICALS = 0 1 1 1 0 1 1 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

STATE WIDTH OPTIMIZED FOR THE ISOTOPE CARBON

----SYSTEM PARAMETERS----

ISOTOPE	ATOMIC MASS	MASS DENSITY	NUCLEAR DENSITY	ALPHA
CARBON	12.011	1.6400	0.08224	0.7162

SYSTEM BUCKLING = 0.0 /SQ.CM.

-----STATE PARAMETERS-----

STATE	U	DU	F	EII	DE	V	VII	DV	RR	NG	STATE
1	0.0	9.665E-02	1.694E 05	1.694E 05	0.0	5.692E 08	5.692E 08	0.0	1.000E 00	8	1
2	2.457E-01	2.457E-01	1.325E 05	1.475E 05	3.690E 04	5.034E 08	5.317E 08	6.581E 07	1.563E 00	8	2
3	4.914E-01	2.457E-01	1.036E 05	1.154E 05	2.886E 04	4.452E 08	4.702E 08	5.820E 07	1.563E 00	8	3
4	7.371E-01	2.457E-01	8.104E 04	9.026E 04	2.257E 04	3.938E 08	4.158E 08	5.147E 07	1.563E 00	0	4
5	9.828E-01	2.457E-01	6.338E 04	7.060E 04	1.765E 04	3.482E 08	3.678E 08	4.552E 07	1.563E 00	9	5
6	1.229E 00	2.457E-01	4.957E 04	5.522E 04	1.381E 04	3.080E 08	3.252E 08	4.026E 07	1.563E 00	9	6
7	1.474E 00	2.457E-01	3.877E 04	4.319E 04	1.080E 04	2.724E 08	2.876E 08	3.560E 07	1.563E 00	0	7
8	1.720E 00	2.457E-01	3.033E 04	3.378E 04	8.447E 03	2.409E 08	2.544E 08	3.149E 07	1.563E 00	10	8
9	1.966E 00	2.457E-01	2.372E 04	2.642E 04	6.607E 03	2.130E 08	2.250E 08	2.785E 07	1.563E 00	10	9
10	2.211E 00	2.457E-01	1.855E 04	2.066E 04	5.168E 03	1.884E 08	1.990E 08	2.463E 07	1.563E 00	0	10
11	2.457E 00	2.457E-01	1.451E 04	1.616E 04	4.042E 03	1.666E 08	1.760E 08	2.178E 07	1.563E 00	11	11
12	2.703E 00	2.457E-01	1.135E 04	1.264E 04	3.161E 03	1.474E 08	1.556E 08	1.926E 07	1.563E 00	11	12
13	2.949E 00	2.457E-01	8.877E 03	9.888E 03	2.473E 03	1.303E 08	1.376E 08	1.704E 07	1.563E 00	0	13
14	3.194E 00	2.457E-01	6.943E 03	7.734E 03	1.934E 03	1.153E 08	1.217E 08	1.507E 07	1.563E 00	12	14
15	3.440E 00	2.457E-01	5.431E 03	6.049E 03	1.513E 03	1.019E 08	1.076E 08	1.332E 07	1.563E 00	12	15
16	3.686E 00	2.457E-01	4.248E 03	4.731E 03	1.183E 03	9.015E 07	9.520E 07	1.178E 07	1.563E 00	0	16
17	3.931E 00	2.457E-01	3.322E 03	3.700E 03	9.254E 02	7.973E 07	8.420E 07	1.042E 07	1.563E 00	13	17
18	4.177E 00	2.457E-01	2.599E 03	2.894E 03	7.238E 02	7.051E 07	7.446E 07	9.217E 06	1.563E 00	13	18
19	4.423E 00	2.457E-01	2.032E 03	2.264E 03	5.661E 02	6.236E 07	6.586E 07	8.152E 06	1.563E 00	0	19
20	4.668E 00	2.457E-01	1.590E 03	1.771E 03	4.428E 02	5.515E 07	5.824E 07	7.209E 06	1.563E 00	14	20
21	4.914E 00	2.457E-01	1.243E 03	1.385E 03	3.463E 02	4.877E 07	5.151E 07	6.376E 06	1.563E 00	14	21
22	5.160E 00	2.457E-01	9.725E 02	1.083E 03	2.709E 02	4.313E 07	4.555E 07	5.639E 06	1.563E 00	0	22
23	5.406E 00	2.457E-01	7.606E 02	8.472E 02	2.119E 02	3.815E 07	4.029E 07	4.987E 06	1.563E 00	15	23
24	5.651E 00	2.457E-01	5.949E 02	6.626E 02	1.657E 02	3.374E 07	3.563E 07	4.410E 06	1.563E 00	15	24
25	5.897E 00	2.457E-01	4.653E 02	5.183E 02	1.296E 02	2.984E 07	3.151E 07	3.900E 06	1.563E 00	15	25
26	6.143E 00	2.457E-01	3.640E 02	4.054E 02	1.014E 02	2.639E 07	2.787E 07	3.449E 06	1.563E 00	0	26
27	6.388E 00	2.457E-01	2.847E 02	3.171E 02	7.929E 01	2.334E 07	2.465E 07	3.051E 06	1.563E 00	16	27
28	6.634E 00	2.457E-01	2.227E 02	2.480E 02	6.201E 01	2.064E 07	2.180E 07	2.698E 06	1.563E 00	16	28
29	6.880E 00	2.457E-01	1.741E 02	1.940E 02	4.850E 01	1.825E 07	1.928E 07	2.386E 06	1.563E 00	0	29
30	7.126E 00	2.457E-01	1.362E 02	1.517E 02	3.794E 01	1.614E 07	1.705E 07	2.110E 06	1.563E 00	17	30
31	7.371E 00	2.457E-01	1.065E 02	1.187E 02	2.967E 01	1.428E 07	1.508E 07	1.866E 06	1.563E 00	17	31
32	7.617E 00	2.457E-01	8.333E 01	9.281E 01	2.321E 01	1.263E 07	1.333E 07	1.651E 06	1.563E 00	0	32
33	7.863E 00	2.457E-01	6.517E 01	7.259E 01	1.815E 01	1.117E 07	1.179E 07	1.460E 06	1.563E 00	18	33
34	8.108E 00	2.457E-01	5.098E 01	5.678E 01	1.420E 01	9.876E 06	1.043E 07	1.291E 06	1.563E 00	18	34
35	8.354E 00	2.457E-01	3.987E 01	4.441E 01	1.111E 01	8.734E 06	9.224E 06	1.142E 06	1.563E 00	0	35
36	8.600E 00	2.457E-01	3.118E 01	3.473E 01	8.686E 00	7.724E 06	8.157E 06	1.010E 06	1.563E 00	19	36
37	8.846E 00	2.457E-01	2.439E 01	2.717E 01	6.794E 00	6.831E 06	7.214E 06	8.930E 05	1.563E 00	19	37
38	9.091E 00	2.457E-01	1.908E 01	2.125E 01	5.314E 00	6.041E 06	6.380E 06	7.897E 05	1.563E 00	0	38
39	9.337E 00	2.457E-01	1.492E 01	1.662E 01	4.156E 00	5.343E 06	5.643E 06	6.984E 05	1.563E 00	20	39
40	9.583E 00	2.457E-01	1.167E 01	1.300E 01	3.251E 00	4.725E 06	4.990E 06	6.177E 05	1.563E 00	20	40
41	9.828E 00	2.457E-01	9.128E 00	1.017E 01	2.542E 00	4.179E 06	4.413E 06	5.463E 05	1.563E 00	0	41
42	1.007E 01	2.457E-01	7.140E 00	7.952E 00	1.989E 00	3.696E 06	3.903E 06	4.831E 05	1.563E 00	21	42
43	1.032E 01	2.457E-01	5.584E 00	6.220E 00	1.555E 00	3.269E 06	3.452E 06	4.273E 05	1.563E 00	21	43
44	1.057E 01	2.457E-01	4.368E 00	4.865E 00	1.217E 00	2.891E 06	3.053E 06	3.779E 05	1.563E 00	0	44
45	1.081E 01	2.457E-01	3.416E 00	3.805E 00	9.515E-01	2.557E 06	2.700E 06	3.342E 05	1.563E 00	22	45
46	1.106E 01	2.457E-01	2.672E 00	2.976E 00	7.442E-01	2.261E 06	2.388E 06	2.956E 05	1.563E 00	22	46
47	1.130E 01	2.457E-01	2.090E 00	2.328E 00	5.821E-01	2.000E 06	2.112E 06	2.614E 05	1.563E 00	0	47
48	1.155E 01	2.457E-01	1.635E 00	1.821E 00	4.553E-01	1.768E 06	1.868E 06	2.312E 05	1.563E 00	23	48
49	1.179E 01	2.457E-01	1.278E 00	1.424E 00	3.561E-01	1.564E 06	1.652E 06	2.044E 05	1.563E 00	23	49
50	1.204E 01	2.457E-01	1.000E 00	1.114E 00	2.785E-01	1.383E 06	1.461E 06	1.808E 05	1.563E 00	0	50
51	2.303E 06	2.303E 06	0.0	0.0	1.000E 00	0.0	0.0	1.383E 06	0.0	0	51

-----SOURCE VECTOR PCP(I,1) (NEUTRONS PER STATE)-----

1.000E 00 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

GENERATING ROUTINE IS BEING CALLED FOR 8 ITERATIONS BEGINNING AT TIME DDT = 7.604E-12 SECONDS.
DDT IS DEFINED FOR VIRTUAL STATE 2 FOR WHICH THE DECAY CONSTANT IS 2.055E 08.

---AT OPERATING ITERATION NO. 1 AND TIME = 0.0 + 0.0 SECONDS,
THE NEUTRON DENSITY (LETHARGY) VECTOR IS WRITTEN BEGINNING WITH VIRTUAL STATE 1.

1	1.000E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	0.0									

ABSORBING STATE POPULATIONS 0.0 0.0 0.0 0.0

MEAN ENERGY (DENSITY AVERAGED) = 1.6936E 05 MEAN VELOCITY = 5.6923E 08
R. M. S. ENERGY = 1.6936E 05 R. M. S. VELOCITY = 5.6923E 08
RELATIVE STANDARD DEVIATION = 0.0 RELATIVE STANDARD DEVIATION = 0.0

NT= 1 NTIME= 1 IPEAK= 2 ZA= 0.400E 00 ZX= 0.0

---AT OPERATING ITERATION NO. 2 AND TIME = 0.0 + 0.195E-08 SECONDS,
THE NEUTRON DENSITY (LETHARGY) VECTOR IS WRITTEN BEGINNING WITH VIRTUAL STATE 1.

1	6.516E-01	9.520E-01	4.188E-01	4.411E-02	2.830E-03	1.219E-04	3.691E-06	8.209E-08	1.376E-09	1.774E-11
11	1.785E-13	1.419E-15	8.601E-18	4.153E-20	1.609E-22	5.030E-25	1.275E-27	2.277E-30	3.243E-33	3.690E-36
21	3.358E-39	2.444E-42	1.428E-45	4.300E-49	8.082E-53	1.164E-56	1.177E-60	7.917E-65	3.660E-69	1.631E-74
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	0.0									

ABSORBING STATE POPULATIONS 0.0 0.0 0.0 0.0

MEAN ENERGY (DENSITY AVERAGED) = 1.5777E 05 MEAN VELOCITY = 5.4844E 08
R. M. S. ENERGY = 1.5889E 05 R. M. S. VELOCITY = 5.4953E 08
RELATIVE STANDARD DEVIATION = 1.1988E-01 RELATIVE STANDARD DEVIATION = 6.2964E-02

NT= 2 NTIME= 1 IPEAK= 2 ZA= 0.400E 00 ZX= 0.0

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                    ---- A MOD5 CALCULATON ----


     EXAMPLE NUMBER 1
         EVALUATION OF ASYMPTOTIC SOLUTION TO SLOWING DOWN EQUATION.
         INFINITE GRAPHITE MODERATOR.  DELTA SOURCE IN TIME AND ENERGY.


THE CENTRAL CORE FLUX-AVERAGED ENERGY IS 1.297E 04 EV.
THE LEAKAGE FLUX-AVERAGED ENERGY IS      0.0       EV.

 AT 6.215E-05 SECONDS--
     0.0    PERCENT OF THE NEUTRONS HAVE SUFFERED NON-FISSION CAPTURE,
     0.0    PERCENT OF THE NEUTRONS HAVE LEAKED FROM THE SYSTEM,
     0.0    PERCENT OF THE NEUTRONS HAVE CAUSED FISSION,
    99.647  PERCENT OF THE NEUTRONS HAVE ENERGY BELOW 1.00E 00 EV,
     0.001  PERCENT ARE STILL SLOWING DOWN,
     0.352  PERCENT ARE LOST FROM THE SYSTEM, AND
     0.0    PERCENT HAVE BEEN BYPASSED BY THE ARRAY.



        **** FINAL STATE VECTOR

0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        3.381E-75  5.320E-66  6.995E-58  1.051E-50  2.351E-44  9.683E-39  8.970E-34  2.246E-29
1.723E-25  4.683E-22  5.090E-19  2.454E-16  5.733E-14  7.036E-12  4.821E-10  1.957E-08  4.938E-07  8.080E-06
9.965E-01  0.0        0.0        0.0


        **** FINAL CORE FLUX VECTOR

0.0        6.038E-02  8.093E-02  8.251E-02  8.348E-02  8.385E-02  8.364E-02  8.330E-02  8.325E-02  8.357E-02
8.397E-02  8.418E-02  8.403E-02  8.377E-02  8.359E-02  8.349E-02  8.336E-02  8.308E-02  8.285E-02  8.288E-02
8.319E-02  8.354E-02  8.372E-02  8.360E-02  8.343E-02  8.345E-02  8.371E-02  8.401E-02  8.415E-02  8.401E-02
8.378E-02  8.365E-02  8.358E-02  8.350E-02  8.325E-02  8.301E-02  8.301E-02  8.327E-02  8.358E-02  8.375E-02
8.362E-02  8.344E-02  8.345E-02  8.370E-02  8.398E-02  8.411E-02  8.397E-02  8.383E-02  8.395E-02  8.444E-02


        **** FINAL SURFACE FLUX VECTOR

0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
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TABLE OF MOMENTS OF DISTRIBUTIONS
(UNITS ARE MICROSECONDS)

	NEUTRON DENSITY AT 1.114E 00 EV.					SLOWING DOWN DENSITY AT 1.000E 00 EV.			
N	CALC.	ASYM.	T.C.	ERROR	N	CALC.	ASYM.	T.C.	ERROR
1	2.4036E 01	2.3702E 01	5.82E-04	1.410	1	2.3900E 01	2.3677E 01	5.09E-04	0.939
2	6.0858E 02	5.9167E 02	5.10E-02	2.857	2	6.0639E 02	5.9145E 02	4.49E-02	2.526
3	1.6347E 04	1.5533E 04	3.63E 00	5.239	3	1.6312E 04	0.0	3.19E 00	0.0
4	4.6519E 05	4.2826E 05	2.43E 02	8.624	4	4.6466E 05	0.0	2.14E 02	0.0
5	1.4006E 07	1.2384E 07	1.60E 04	13.101	5	1.3998E 07	0.0	1.41E 04	0.0
-1	4.5001E-02	4.4500E-02	0.0	1.125	-1	4.4474E-02	0.0	0.0	0.0
-2	2.1379E-03	2.0919E-03	0.0	2.201	-2	2.1053E-03	0.0	0.0	0.0
-3	1.0823E-04	1.0403E-04	0.0	4.033	-3	1.0621E-04	0.0	0.0	0.0
RSD	2.3101E-01	2.3065E-01		0.158		2.4824E-01	2.3453E-01		5.848

CALC. = CALCULATED FROM DISTRIBUTION AND CORRECTED FOR TRUNCATION ERROR
ASYM. = ERIKSSON'S ASYMPTOTIC MOMENTS
T.C. = TRUNCATION CORRECTION
ERROR = PERCENT DEVIATION OF CALCULATED FROM ASYMPTOTIC
RSD = RELATIVE STANDARD DEVIATION

**** RATIO OF COMPUTED TO EXACT MOMENTS OF DENSITY

N	CORMOM/EXM
1	1.01410389
2	1.02857208
3	1.05239391
4	1.08623600
5	1.13100910
-1	1.01125050
-2	1.02201271
-3	1.04032803

INTERPOLATED DISTRIBUTIONS
DTI = 5.0E-07 SECONDS

N	TIME	DENSITY	S.D.D.	N
1	1.250E-07	5.126E-61	3.172E-61	1
2	2.500E-07	9.440E-47	8.181E-47	2
3	3.750E-07	5.341E-39	4.635E-39	3
4	5.000E-07	9.142E-34	8.771E-34	4
5	6.250E-07	7.121E-30	6.552E-30	5
6	7.500E-07	8.286E-27	7.454E-27	6
7	8.750E-07	2.636E-24	2.360E-24	7
8	1.000E-06	3.750E-22	3.344E-22	8
9	1.125E-06	2.279E-20	2.079E-20	9
10	1.250E-06	8.173E-19	7.571E-19	10
11	1.375E-06	1.924E-17	1.801E-17	11
12	1.500E-06	3.212E-16	3.032E-16	12
13	1.625E-06	4.034E-15	3.831E-15	13
14	1.750E-06	3.988E-14	3.805E-14	14
15	1.875E-06	3.216E-13	3.079E-13	15
16	2.000E-06	2.339E-12	1.991E-12	16
17	2.125E-06	1.345E-11	1.080E-11	17
18	2.250E-06	6.787E-11	5.517E-11	18
19	2.375E-06	3.049E-10	2.506E-10	19
20	2.500E-06	1.235E-09	1.026E-09	20
21	3.000E-06	1.447E-07	1.242E-07	21
22	3.500E-06	6.231E-06	5.481E-06	22
23	4.000E-06	1.362E-04	1.186E-04	23
24	4.500E-06	1.706E-03	1.507E-03	24
25	5.000E-06	1.439E-02	1.288E-02	25
26	5.500E-06	8.898E-02	8.056E-02	26
27	6.000E-06	4.288E-01	3.921E-01	27
28	6.500E-06	1.685E 00	1.555E 00	28
29	7.000E-06	5.594E 00	5.200E 00	29
30	7.500E-06	1.611E 01	1.507E 01	30
31	8.000E-06	4.165E 01	4.051E 01	31
32	8.500E-06	9.553E 01	9.315E 01	32
33	9.000E-06	2.004E 02	1.959E 02	33
34	9.500E-06	3.891E 02	3.810E 02	34
35	1.000E-05	7.056E 02	6.920E 02	35
36	1.050E-05	1.204E 03	1.183E 03	36
37	1.100E-05	1.948E 03	1.916E 03	37
38	1.150E-05	3.004E 03	2.958E 03	38
39	1.200E-05	4.436E 03	4.374E 03	39
40	1.250E-05	6.303E 03	6.221E 03	40
41	1.300E-05	8.645E 03	8.542E 03	41
42	1.350E-05	1.149E 04	1.136E 04	42
43	1.400E-05	1.483E 04	1.468E 04	43
44	1.450E-05	1.864E 04	1.846E 04	44
45	1.500E-05	2.287E 04	2.267E 04	45
46	1.550E-05	2.743E 04	2.722E 04	46
47	1.600E-05	3.225E 04	3.202E 04	47
48	1.650E-05	3.720E 04	3.639E 04	48
49	1.700E-05	4.215E 04	4.067E 04	49
50	1.750E-05	4.699E 04	4.555E 04	50

INTERPOLATED DISTRIBUTIONS
DTI = 5.0E-07 SECONDS

N	TIME	DENSITY	S.D.D.	N
101	4.300E-05	1.449E 03	1.451E 03	101
102	4.350E-05	1.256E 03	1.259E 03	102
103	4.400E-05	1.088E 03	1.090E 03	103
104	4.450E-05	9.413E 02	9.436E 02	104
105	4.500E-05	8.135E 02	8.156E 02	105
106	4.550E-05	7.023E 02	7.043E 02	106
107	4.600E-05	6.057E 02	6.075E 02	107
108	4.650E-05	5.219E 02	5.235E 02	108
109	4.700E-05	4.493E 02	4.507E 02	109
110	4.750E-05	3.864E 02	3.877E 02	110
111	4.800E-05	3.320E 02	3.332E 02	111
112	4.850E-05	2.850E 02	2.861E 02	112
113	4.900E-05	2.445E 02	2.455E 02	113
114	4.950E-05	2.096E 02	2.105E 02	114
115	5.000E-05	1.795E 02	1.802E 02	115
116	5.050E-05	1.536E 02	1.543E 02	116
117	5.100E-05	1.314E 02	1.319E 02	117
118	5.150E-05	1.123E 02	1.128E 02	118
119	5.200E-05	9.592E 01	9.627E 01	119
120	5.250E-05	8.187E 01	8.225E 01	120
121	5.300E-05	6.984E 01	7.024E 01	121
122	5.350E-05	5.953E 01	5.981E 01	122
123	5.400E-05	5.072E 01	5.102E 01	123
124	5.450E-05	4.319E 01	4.342E 01	124
125	5.500E-05	3.675E 01	3.690E 01	125
126	5.550E-05	3.126E 01	3.133E 01	126
127	5.600E-05	2.658E 01	2.660E 01	127
128	5.650E-05	2.258E 01	2.268E 01	128
129	5.700E-05	1.918E 01	1.924E 01	129
130	5.750E-05	1.628E 01	1.629E 01	130
131	5.800E-05	1.381E 01	1.380E 01	131
132	5.850E-05	1.171E 01	1.168E 01	132
133	5.900E-05	9.930E 00	9.902E 00	133
134	5.950E-05	8.415E 00	8.367E 00	134
135	6.000E-05	7.128E 00	7.072E 00	135
136	6.050E-05	6.035E 00	6.004E 00	136
137	6.100E-05	5.108E 00	5.057E 00	137
138	6.150E-05	4.322E 00	4.245E 00	138
139	6.200E-05	3.655E 00	3.643E 00	139

****
* MOD-5 *
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EXAMPLE NUMBER 2
STUDY OF SLOWING DOWN OF NEUTRONS FROM A 0.5 MICROSECOND, 2.46 MEV PULSED SOURCE (D,D). DEMONSTRATES TRAVELING ARRAY.

NUMBER OF REAL TRANSIENT STATES	71
NUMBER OF VIRTUAL TRANSIENT STATES	109
NUMBER OF SCATTTERING ISOTOPES	1
NUMBER OF FISSILE ISOTOPES	0
ROW GENERATICN CRITERION	0.0010
ARRAY GENERATICN CRITERION	0.5000
ARRAY SQUARING CRITERICN	0.2500

LOGICALS = 0 1 0 0 0 1 1 0 1 0 0 0 0 0 1 0 0 1 0 0 0 0 0 0 0 0 0 0

STATE WIDTH OPTIMIZED FOR THE ISOTOPE CARBON

----SYSTEM PARAMETERS----

ISOTOPE	ATCMIC MASS	MASS DENSITY	NUCLEAR DENSITY	ALPHA
CARBON	12.011	1.6400	0.08224	0.7162

SYSTEM BUCKLING = 0.0 /SQ.CM.

-----NORMALIZED TRANSFER COEFFICIENTS FOR INELASTIC SCATTERING-----

H(I,J)

I \ J	1	2	3	4	5	6	7	8	9	10	11	12
----- CARBON -----												
NEUTRON YIELD FROM INELASTIC SCATTERING IN GROUP 1 = 1.00												
1	0.0	0.0	0.200	0.571	0.143	0.057	0.029	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.625	0.250	0.125	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

GENERATING ROUTINE IS BEING CALLED FOR 8 ITERATIONS BEGINNING AT TIME DDT = 6.672E-12 SECONDS.
DDT IS DEFINED FOR VIRTUAL STATE 2 FOR WHICH THE DECAY CONSTANT IS 2.927E 08.

---AT OPERATING ITERATION NO. 1 AND TIME = 0.0 + 0.0 SECONDS,
THE NEUTRON DENSITY (LETHARGY) VECTOR IS WRITTEN BEGINNING WITH VIRTUAL STATE 1.

1	0.0	2.485E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
71	0.0									

ABSORBING STATE POPULATIONS 0.0 0.0 0.0 0.0

MEAN ENERGY (DENSITY AVERAGED) = 2.2857E 06
R. M. S. ENERGY = 2.2857E 06
RELATIVE STANDARD DEVIATION = 0.0

MEAN VELOCITY = 2.0916E 09
R. M. S. VELOCITY = 2.0916E 09
RELATIVE STANDARD DEVIATION = 0.0

NT= 1 NTIME= 1 IPEAK= 2 ZA= 0.500E 00 ZX= 0.0

---AT OPERATING ITERATION NO. 2 AND TIME = 0.0 + 0.171E-08 SECONDS,
THE NEUTRON DENSITY (LETHARGY) VECTOR IS WRITTEN BEGINNING WITH VIRTUAL STATE 1.

1	0.0	4.167E-02	3.559E-03	3.490E-03	6.180E-04	3.081E-04	4.481E-05	1.540E-05	2.658E-06	6.978E-07
11	1.020E-07	2.221E-08	3.365E-09	6.140E-10	8.021E-11	1.240E-11	1.516E-12	2.549E-13	2.804E-14	4.023E-15
21	3.969E-16	4.695E-17	4.743E-18	5.241E-19	4.451E-20	4.349E-21	3.351E-22	2.972E-23	2.055E-24	1.621E-25
31	1.008E-26	7.109E-28	4.063E-29	2.571E-30	1.323E-31	7.531E-33	3.498E-34	1.790E-35	7.086E-37	3.262E-38
41	1.161E-39	4.817E-41	1.542E-42	5.776E-44	1.665E-45	5.640E-47	1.465E-48	4.469E-50	8.348E-52	2.287E-53
51	3.777E-55	9.303E-57	1.356E-58	3.007E-60	3.861E-62	7.713E-64	8.708E-66	1.560E-67	7.485E-70	1.186E-71
61	4.417E-74	6.185E-76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
71	0.0									

---- AT OPERATING ITERATION NUMBER 154 THE ARRAY HAS BEEN SQUARED
THE PULSE PEAK IS LOCATED IN VIRTUAL STATE 48, AND THE NEW TIME STEP IS 1.366E-08.

```
NT=155  NTIME= 4  IPEAK= 48  ZA= 0.468E 00  ZX= 0.641E-07
NT=156  NTIME= 4  IPEAK= 48  ZA= 0.468E 00  ZX= 0.107E-06
NT=157  NTIME= 4  IPEAK= 49  ZA= 0.437E 00  ZX= 0.174E-06
NT=158  NTIME= 4  IPEAK= 49  ZA= 0.437E 00  ZX= 0.278E-06
NT=159  NTIME= 4  IPEAK= 49  ZA= 0.437E 00  ZX= 0.437E-06
NT=160  NTIME= 4  IPEAK= 50  ZA= 0.408E 00  ZX= 0.674E-06
NT=161  NTIME= 4  IPEAK= 50  ZA= 0.408E 00  ZX= 0.102E-05
NT=162  NTIME= 4  IPEAK= 51  ZA= 0.381E 00  ZX= 0.153E-05
NT=163  NTIME= 4  IPEAK= 51  ZA= 0.381E 00  ZX= 0.226E-05
NT=164  NTIME= 4  IPEAK= 51  ZA= 0.381E 00  ZX= 0.330E-05
NT=165  NTIME= 4  IPEAK= 51  ZA= 0.381E 00  ZX= 0.474E-05
NT=166  NTIME= 4  IPEAK= 52  ZA= 0.356E 00  ZX= 0.672E-05
NT=167  NTIME= 4  IPEAK= 52  ZA= 0.356E 00  ZX= 0.942E-05
NT=168  NTIME= 4  IPEAK= 52  ZA= 0.356E 00  ZX= 0.131E-04
NT=169  NTIME= 4  IPEAK= 53  ZA= 0.332E 00  ZX= 0.179E-04
NT=170  NTIME= 4  IPEAK= 53  ZA= 0.332E 00  ZX= 0.243E-04
NT=171  NTIME= 4  IPEAK= 53  ZA= 0.332E 00  ZX= 0.327E-04
NT=172  NTIME= 4  IPEAK= 54  ZA= 0.310E 00  ZX= 0.436E-04
NT=173  NTIME= 4  IPEAK= 54  ZA= 0.310E 00  ZX= 0.575E-04
NT=174  NTIME= 4  IPEAK= 54  ZA= 0.310E 00  ZX= 0.753E-04
NT=175  NTIME= 4  IPEAK= 54  ZA= 0.310E 00  ZX= 0.977E-04
NT=176  NTIME= 4  IPEAK= 55  ZA= 0.289E 00  ZX= 0.126E-03
NT=177  NTIME= 4  IPEAK= 55  ZA= 0.289E 00  ZX= 0.161E-03
NT=178  NTIME= 4  IPEAK= 55  ZA= 0.289E 00  ZX= 0.204E-03
NT=179  NTIME= 4  IPEAK= 55  ZA= 0.289E 00  ZX= 0.257E-03
NT=180  NTIME= 4  IPEAK= 56  ZA= 0.270E 00  ZX= 0.321E-03
NT=181  NTIME= 4  IPEAK= 56  ZA= 0.270E 00  ZX= 0.399E-03
NT=182  NTIME= 4  IPEAK= 56  ZA= 0.270E 00  ZX= 0.493E-03
NT=183  NTIME= 4  IPEAK= 57  ZA= 0.252E 00  ZX= 0.605E-03
NT=184  NTIME= 4  IPEAK= 57  ZA= 0.252E 00  ZX= 0.739E-03
NT=185  NTIME= 4  IPEAK= 57  ZA= 0.252E 00  ZX= 0.897E-03
```


AT OPERATING ITERATION 186 THE ARRAY SIZE HAS BEEN REDUCED FROM 71 TO 66.**

-----STATE PARAMETERS-----

STATE	U	DU	E	EII	DE	V	VII	DV	RR	NG	STATE
1	0.0	5.799E-02	2.460E 06	0.0	0.0	2.169E 09	0.0	0.0	1.000E 00	4	1
2	1.374E-01	1.374E-01	2.144E 06	2.286E 06	3.159E 05	2.025E 09	2.092E 09	1.441E 08	1.279E 00	4	2
3	2.749E-01	1.374E-01	1.869E 06	1.992E 06	2.753E 05	1.891E 09	1.953E 09	1.345E 08	1.279E 00	4	3
4	4.123E-01	1.374E-01	1.629E 06	1.736E 06	2.400E 05	1.765E 09	1.823E 09	1.256E 08	1.279E 00	4	4
5	5.498E-01	1.374E-01	1.420E 06	1.513E 06	2.092E 05	1.648E 09	1.702E 09	1.172E 08	1.279E 00	4	5
6	6.872E-01	1.374E-01	1.237E 06	1.319E 06	1.823E 05	1.539E 09	1.589E 09	1.095E 08	1.279E 00	0	6
7	8.247E-01	1.374E-01	1.078E 06	1.150E 06	1.589E 05	1.436E 09	1.483E 09	1.022E 08	1.279E 00	5	7
8	9.621E-01	1.374E-01	9.399E 05	1.002E 06	1.385E 05	1.341E 09	1.385E 09	9.540E 07	1.279E 00	5	8
9	1.100E 00	1.374E-01	8.192E 05	8.733E 05	1.207E 05	1.252E 09	1.293E 09	8.906E 07	1.279E 00	5	9
10	1.237E 00	1.374E-01	7.140E 05	7.612E 05	1.052E 05	1.169E 09	1.207E 09	8.315E 07	1.279E 00	0	10
11	1.374E 00	1.374E-01	6.223E 05	6.634E 05	9.169E 04	1.091E 09	1.127E 09	7.762E 07	1.279E 00	6	11
12	1.512E 00	1.374E-01	5.424E 05	5.782E 05	7.992E 04	1.019E 09	1.052E 09	7.247E 07	1.279E 00	6	12
13	1.649E 00	1.374E-01	4.728E 05	5.040E 05	6.965E 04	9.510E 08	9.822E 08	6.766E 07	1.279E 00	6	13
14	1.787E 00	1.374E-01	4.120E 05	4.393E 05	6.071E 04	8.879E 08	9.169E 08	6.316E 07	1.279E 00	6	14
15	1.924E 00	1.374E-01	3.591E 05	3.829E 05	5.291E 04	8.289E 08	8.560E 08	5.897E 07	1.279E 00	0	15
16	2.062E 00	1.374E-01	3.130E 05	3.337E 05	4.612E 04	7.739E 08	7.992E 08	5.505E 07	1.279E 00	7	16
17	2.199E 00	1.374E-01	2.728E 05	2.908E 05	4.020E 04	7.225E 08	7.461E 08	5.140E 07	1.279E 00	7	17
18	2.337E 00	1.374E-01	2.378E 05	2.535E 05	3.503E 04	6.745E 08	6.965E 08	4.798E 07	1.279E 00	7	18
19	2.474E 00	1.374E-01	2.072E 05	2.209E 05	3.054E 04	6.297E 08	6.503E 08	4.480E 07	1.279E 00	7	19
20	2.611E 00	1.374E-01	1.806E 05	1.926E 05	2.661E 04	5.879E 08	6.071E 08	4.182E 07	1.279E 00	0	20
21	2.749E 00	1.374E-01	1.574E 05	1.678E 05	2.320E 04	5.488E 08	5.668E 08	3.904E 07	1.279E 00	8	21
22	2.886E 00	1.374E-01	1.372E 05	1.463E 05	2.022E 04	5.124E 08	5.291E 08	3.645E 07	1.279E 00	8	22
23	3.024E 00	1.374E-01	1.196E 05	1.275E 05	1.762E 04	4.783E 08	4.940E 08	3.403E 07	1.279E 00	8	23
24	3.161E 00	1.374E-01	1.042E 05	1.111E 05	1.536E 04	4.466E 08	4.612E 08	3.177E 07	1.279E 00	8	24
25	3.299E 00	1.374E-01	9.085E 04	9.685E 04	1.339E 04	4.169E 08	4.306E 08	2.966E 07	1.279E 00	0	25
26	3.436E 00	1.374E-01	7.918E 04	8.442E 04	1.167E 04	3.892E 08	4.020E 08	2.769E 07	1.279E 00	9	26

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---- A MOD5 CALCULATON ----


     EXAMPLE NUMBER 2
         STUDY OF SLOWING DOWN OF NEUTRONS FROM A 0.5 MICROSECOND, 2.46
         MEV PULSED SOURCE (D,D).  DEMONSTRATES TRAVELING ARRAY.


THE CENTRAL CORE FLUX-AVERAGED ENERGY IS 2.911E 05 EV.
THE LEAKAGE FLUX-AVERAGED ENERGY IS      0.0       EV.

 AT 9.655E-05 SECONDS--
     0.0   PERCENT OF THE NEUTRONS HAVE SUFFERED NON-FISSION CAPTURE,
     0.0   PERCENT OF THE NEUTRONS HAVE LEAKED FROM THE SYSTEM,
     0.0   PERCENT OF THE NEUTRONS HAVE CAUSED FISSION,
    97.965 PERCENT OF THE NEUTRONS HAVE ENERGY BELOW 1.01E 00 EV,
     0.002 PERCENT ARE STILL SLOWING DOWN,
     2.035 PERCENT ARE LOST FROM THE SYSTEM, AND
     0.113 PERCENT HAVE BEEN BYPASSED BY THE ARRAY.


         **** FINAL STATE VECTOR

 0.0        -1.082E-46 -7.133E-43 -1.710E-39 -1.981E-36 -3.463E-33 -5.792E-33 -2.452E-32 -1.302E-31 -1.067E-30
-2.890E-30 -1.530E-29 -1.199E-28 -1.724E-27 -2.553E-26 -5.581E-26 -2.586E-25 -1.518E-24 -1.290E-23 -1.450E-22
-9.646E-22 -1.019E-20 -1.329E-19 -1.872E-18 -2.323E-17 -1.756E-16 -1.516E-15 -1.150E-14 -6.117E-14  1.113E-14
 3.989E-12  5.910E-11  5.902E-10  4.662E-09  3.063E-08  1.714E-07  7.507E-07  3.076E-06  1.124E-05  3.678E-05
 1.081E-04  2.865E-04  6.874E-04  0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        5.392E-77  1.747E-71  2.433E-66  1.537E-61  4.634E-57
 7.053E-53  5.677E-49  2.517E-45  6.360E-42  9.513E-39  8.785E-36  5.174E-33  1.991E-30  5.119E-28  9.069E-26
 1.132E-23  1.018E-21  6.719E-20  3.326E-18  1.256E-16  3.678E-15  8.455E-14  1.553E-12  9.797E-01  0.0
 0.0        0.0


         **** FINAL CORE FLUX VECTOR

 0.0        2.794E-01  9.202E-02  1.371E-01  1.270E-01  1.433E-01  8.722E-02  9.069E-02  9.216E-02  9.335E-02
 7.198E-02  7.375E-02  7.542E-02  7.707E-02  7.518E-02  5.276E-02  5.403E-02  5.529E-02  5.649E-02  5.708E-02
 5.243E-02  5.348E-02  5.450E-02  5.548E-02  5.567E-02  5.290E-02  5.376E-02  5.459E-02  5.539E-02  5.615E-02
 5.528E-02  5.599E-02  5.668E-02  5.734E-02  5.799E-02  5.860E-02  5.764E-02  5.822E-02  5.878E-02  5.932E-02
 5.985E-02  6.035E-02  6.081E-02  6.119E-02  6.176E-02  6.220E-02  6.266E-02  6.303E-02  6.335E-02  6.362E-02
 6.384E-02  6.400E-02  6.413E-02  6.422E-02  6.430E-02  6.437E-02  6.445E-02  6.453E-02  6.462E-02  6.473E-02
 6.485E-02  6.494E-02  6.500E-02  6.500E-02  6.495E-02  6.485E-02  6.477E-02  6.468E-02  6.463E-02  6.466E-02
 6.466E-02  6.480E-02  6.491E-02  6.497E-02  6.496E-02  6.488E-02  6.478E-02  6.464E-02  6.455E-02  6.453E-02
 6.458E-02  6.468E-02  6.478E-02  6.483E-02  6.479E-02  6.469E-02  6.454E-02  6.443E-02  6.434E-02  6.433E-02
 6.440E-02  6.452E-02  6.464E-02  6.469E-02  6.467E-02  6.456E-02  6.442E-02  6.430E-02  6.422E-02  6.422E-02
 6.430E-02  6.442E-02  6.454E-02  6.461E-02  6.459E-02  6.450E-02  6.435E-02  6.425E-02


         **** FINAL SURFACE FLUX VECTOR

 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
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*********
* MOD-5 *
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EXAMPLE NUMBER 3
STUDY OF SLOWING DOWN SPECTRA IN REPRESENTATIVE FAST MULTIPLYING ASSEMBLY. FISSION SOURCE - DELTA FUNCTION IN TIME.

NUMBER OF REAL TRANSIENT STATES	71
NUMBER OF VIRTUAL TRANSIENT STATES	121
NUMBER OF SCATTTERING ISOTOPES	4
NUMBER OF FISSILE ISOTOPES	2
ROW GENERATION CRITERION	0.0010
ARRAY GENERATION CRITERION	0.4000
ARRAY SQUARING CRITERION	0.2000

LOGICALS = 0 1 0 0 1 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0

----SYSTEM PARAMETERS----

ISOTOPE	ATOMIC MASS	MASS DENSITY	NUCLEAR DENSITY	ALPHA
ALUMINUM	26.980	0.8480	0.01893	0.8621
IRON	55.850	0.9650	0.01041	0.9309
U-235	235.000	2.6220	0.00672	0.9831
U-238	238.000	3.0160	0.00763	0.9833

SYSTEM BUCKLING = 0.007200/SQ.CM.

-----TABLE OF SCALE FACTORS-----

GROUP	ISOTOPIC INDEX 1	2	3	4	5
1	1.00	0.50	0.10	0.10	1.00
2	1.00	0.50	0.10	0.10	1.00
3	1.00	0.50	0.10	0.10	1.00
4	1.00	0.50	0.10	0.10	1.00
5	1.00	0.50	0.10	0.10	1.00
6	1.00	0.50	0.10	0.10	1.00
7	1.00	0.50	0.10	0.10	1.00
8	1.00	0.50	0.10	0.10	1.00
9	1.00	0.50	0.10	0.10	1.00
10	1.00	0.50	0.10	0.10	1.00
11	1.00	0.50	0.10	0.10	1.00
12	1.00	0.50	0.10	0.10	1.00
13	1.00	0.50	0.10	0.10	1.00
14	1.00	0.50	0.10	0.10	1.00
15	1.00	0.50	0.10	0.10	1.00
16	1.00	0.50	0.10	0.10	1.00
17	1.00	0.50	0.10	0.10	1.00
18	1.00	0.50	0.10	0.10	1.00
19	1.00	0.50	0.10	0.10	1.00
20	1.00	0.50	0.10	0.10	1.00
21	1.00	0.50	0.10	0.10	1.00
22	1.00	0.50	0.10	0.10	1.00
23	1.00	0.50	0.10	0.10	1.00
24	1.00	0.50	0.10	0.10	1.00
25	1.00	0.50	0.10	0.10	1.00
26	1.00	0.50	0.10	0.10	1.00

-----MACROSCOPIC CROSS SECTIONS-----

GROUP	TOTAL	TRANSPORT	LEAKAGE	ALUMINUM ELASTIC	ALUMINUM CAPTURE	ALUMINUM INELASTIC	ALUMINUM FISSION	ALUMINUM COSINE
1	0.107061	0.090272	0.025314	0.018931	0.001798	0.015145	0.0	0.640000
2	0.112632	0.104060	0.022106	0.027071	0.000435	0.014198	0.0	0.570000
3	0.119265	0.122357	0.018922	0.038808	0.000038	0.012305	0.0	0.470000
4	0.121009	0.133811	0.017357	0.047257	0.000008	0.009465	0.0	0.360000
5	0.115220	0.135009	0.017208	0.057708	0.000008	0.002461	0.0	0.290000
6	0.126482	0.168122	0.013909	0.073779	0.000013	0.0	0.0	0.200000
7	0.126381	0.192480	0.012189	0.070530	0.000019	0.0	0.0	0.110000
8	0.148860	0.253762	0.009297	0.088818	0.000051	0.0	0.0	0.060000
9	0.146171	0.276300	0.008550	0.075695	0.000027	0.0	0.0	0.040000
10	0.196624	0.347736	0.006816	0.096353	0.000071	0.0	0.0	0.030000
11	0.102969	0.269083	0.008776	0.018931	0.000019	0.0	0.0	0.024700
12	0.151897	0.359611	0.006594	0.034197	0.000379	0.0	0.0	0.024700
13	0.145812	0.351808	0.006738	0.026503	0.000013	0.0	0.0	0.024700
14	0.173145	0.356509	0.006650	0.026503	0.000019	0.0	0.0	0.024700
15	0.227198	0.456014	0.005213	0.026503	0.000028	0.0	0.0	0.024700
16	0.266859	0.458591	0.005184	0.026503	0.000040	0.0	0.0	0.024700
17	0.338818	0.391726	0.006059	0.026503	0.000059	0.0	0.0	0.024700
18	0.405463	0.445709	0.005332	0.026503	0.000087	0.0	0.0	0.024700
19	0.521168	0.462397	0.005142	0.026503	0.000127	0.0	0.0	0.024700
20	0.630008	0.449679	0.005286	0.026503	0.000189	0.0	0.0	0.024700

GROUP	IRON ELASTIC	IRON CAPTURE	IRON INELASTIC	IRON FISSION	IRON COSINE	U-235 ELASTIC	U-235 CAPTURE	U-235 INELASTIC	U-235 FISSION	U-235 COSINE
1	0.02071	0.00037	0.01426	0.0	0.83000	0.02352	0.00013	0.00692	0.01176	0.84000
2	0.02556	0.00005	0.01405	0.0	0.72000	0.02890	0.00020	0.01290	0.00773	0.80000
3	0.02446	0.00002	0.01176	0.0	0.45000	0.03024	0.00027	0.01284	0.00840	0.71000
4	0.02436	0.00003	0.00937	0.0	0.32000	0.02621	0.00040	0.01183	0.00860	0.55000
5	0.02525	0.00004	0.00395	0.0	0.24000	0.02587	0.00081	0.00927	0.00840	0.45000
6	0.03637	0.00004	0.00010	0.0	0.17000	0.03226	0.00114	0.00806	0.00827	0.35000
7	0.03024	0.00005	0.0	0.0	0.08000	0.04395	0.00168	0.00672	0.00948	0.23000
8	0.03651	0.00005	0.0	0.0	0.05000	0.05712	0.00269	0.00403	0.01142	0.13000
9	0.05038	0.00006	0.0	0.0	0.03000	0.06465	0.00403	0.00121	0.01411	0.07000
10	0.09909	0.00010	0.0	0.0	0.02000	0.06922	0.00672	0.00040	0.01781	0.04000
11	0.04152	0.00005	0.0	0.0	0.01190	0.07459	0.00996	0.0	0.02257	0.02000
12	0.08591	0.00004	0.0	0.0	0.01190	0.08400	0.01378	0.0	0.02887	0.01000
13	0.06130	0.00011	0.0	0.0	0.01190	0.09895	0.01773	0.0	0.03482	0.00270
14	0.07691	0.00069	0.0	0.0	0.01190	0.10575	0.02359	0.0	0.04532	0.00270
15	0.10437	0.00016	0.0	0.0	0.01190	0.09700	0.03759	0.0	0.06592	0.00270
16	0.11447	0.00029	0.0	0.0	0.01190	0.08400	0.05264	0.0	0.08974	0.00270
17	0.11864	0.00039	0.0	0.0	0.01190	0.08199	0.06908	0.0	0.11596	0.00270
18	0.11864	0.00055	0.0	0.0	0.01190	0.08064	0.09925	0.0	0.16676	0.00270
19	0.11864	0.00075	0.0	0.0	0.01190	0.08064	0.12780	0.0	0.20258	0.00270
20	0.11864	0.00109	0.0	0.0	0.01190	0.08064	0.20006	0.0	0.18703	0.00270

GROUP	U-238 ELASTIC	U-238 CAPTURE	U-238 INELASTIC	U-238 FISSION	U-238 COSINE	ELASTIC	CAPTURE	INELASTIC	FISSION	COSINE
1	0.02671	0.0	0.01374	0.00763	0.84000	0.0	0.0	0.0	0.0	0.0
2	0.03358	0.00008	0.01916	0.00443	0.80000	0.0	0.0	0.0	0.0	0.0
3	0.03435	0.00015	0.01984	0.00443	0.71000	0.0	0.0	0.0	0.0	0.0
4	0.03282	0.00046	0.01717	0.00374	0.53000	0.0	0.0	0.0	0.0	0.0
5	0.03511	0.00099	0.01641	0.00015	0.42000	0.0	0.0	0.0	0.0	0.0
6	0.04595	0.00099	0.01259	0.0	0.33000	0.0	0.0	0.0	0.0	0.0
7	0.06411	0.00114	0.00801	0.0	0.21000	0.0	0.0	0.0	0.0	0.0
8	0.08167	0.00168	0.00420	0.0	0.12000	0.0	0.0	0.0	0.0	0.0
9	0.09388	0.00267	0.00145	0.0	0.07000	0.0	0.0	0.0	0.0	0.0
10	0.09922	0.00350	0.0	0.0	0.04000	0.0	0.0	0.0	0.0	0.0
11	0.10228	0.00452	0.0	0.0	0.02000	0.0	0.0	0.0	0.0	0.0
12	0.11053	0.00569	0.0	0.0	0.00270	0.0	0.0	0.0	0.0	0.0
13	0.11209	0.00815	0.0	0.0	0.00270	0.0	0.0	0.0	0.0	0.0
14	0.08896	0.01244	0.0	0.0	0.00270	0.0	0.0	0.0	0.0	0.0
15	0.11664	0.01839	0.0	0.0	0.00270	0.0	0.0	0.0	0.0	0.0
16	0.08605	0.01921	0.0	0.0	0.00270	0.0	0.0	0.0	0.0	0.0
17	0.15891	0.03736	0.0	0.0	0.00270	0.0	0.0	0.0	0.0	0.0
18	0.09951	0.02964	0.0	0.0	0.00270	0.0	0.0	0.0	0.0	0.0
19	0.16920	0.07396	0.0	0.0	0.00270	0.0	0.0	0.0	0.0	0.0
20	0.12030	0.13044	0.0	0.0	0.00270	0.0	0.0	0.0	0.0	0.0

**** (N,2N) REACTIONS OCCUR IN IRON . ROW SUM ERRORS WILL NOT STOP EXECUTION OF THIS PROBLEM

**** (N,2N) REACTIONS OCCUR IN U-235 . ROW SUM ERRORS WILL NOT STOP EXECUTION OF THIS PROBLEM

**** (N,2N) REACTIONS OCCUR IN U-238 . ROW SUM ERRORS WILL NOT STOP EXECUTION OF THIS PROBLEM

-----NORMALIZED TRANSFER COEFFICIENTS FOR INELASTIC SCATTERING-----

H(I,J)

I \ J	1	2	3	4	5	6	7	8	9	10	11	12
-----ALUMINUM-----												
NEUTRON YIELD FROM INELASTIC SCATTERING IN GROUP 1 = 1.00												
1	0.012	0.375	0.187	0.313	0.225	0.125	0.050	0.012	0.0	0.0	0.0	0.0
2	0.0	0.167	0.347	0.293	0.147	0.093	0.040	0.013	0.0	0.0	0.0	0.0
3	0.0	0.0	0.092	0.477	0.200	0.154	0.062	0.015	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.080	0.540	0.380	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.231	0.462	0.231	0.077	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
----- IRON -----												
NEUTRON YIELD FROM INELASTIC SCATTERING IN GROUP 1 = 1.00												
1	0.077	0.158	0.139	0.292	0.248	0.161	0.058	0.029	0.007	0.0	0.0	0.0
2	0.0	0.089	0.163	0.230	0.244	0.170	0.074	0.022	0.007	0.0	0.0	0.0
3	0.0	0.0	0.159	0.531	0.124	0.115	0.044	0.027	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.167	0.511	0.278	0.033	0.011	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.027	0.405	0.405	0.135	0.027	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	1.000	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
----- U-235 -----												
NEUTRON YIELD FROM INELASTIC SCATTERING IN GROUP 1 = 1.79												
1	0.0	0.010	0.049	0.243	0.417	0.544	0.340	0.136	0.039	0.010	0.0	0.0
2	0.0	0.010	0.042	0.182	0.281	0.266	0.135	0.057	0.021	0.005	0.0	0.0
3	0.0	0.0	0.052	0.141	0.277	0.283	0.157	0.063	0.021	0.005	0.0	0.0
4	0.0	0.0	0.0	0.114	0.199	0.324	0.227	0.091	0.034	0.011	0.0	0.0
5	0.0	0.0	0.0	0.0	0.145	0.370	0.268	0.145	0.058	0.014	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.367	0.367	0.183	0.067	0.017	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.610	0.380	0.010	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.350	0.483	0.133	0.033	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.500	0.389	0.111	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.833	0.167	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
----- U-238 -----												
NEUTRON YIELD FROM INELASTIC SCATTERING IN GROUP 1 = 1.44												
1	0.0	0.006	0.061	0.228	0.361	0.417	0.239	0.089	0.028	0.011	0.0	0.0
2	0.0	0.008	0.046	0.159	0.279	0.291	0.151	0.052	0.016	0.004	0.0	0.0
3	0.0	0.0	0.023	0.112	0.254	0.323	0.181	0.077	0.023	0.008	0.0	0.0
4	0.0	0.0	0.0	0.062	0.258	0.364	0.200	0.084	0.027	0.004	0.0	0.0
5	0.0	0.0	0.0	0.0	0.535	0.228	0.158	0.060	0.014	0.005	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.794	0.188	0.0	0.012	0.006	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.705	0.276	0.019	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.582	0.418	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.368	0.474	0.158	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

-----TRANSFER COEFFICIENT ROW SUM CRITERIA IS NOT SATISFIED-----,

ROW SUMS, BEGINNING WITH ROW 1

0.0	1.10716629	1.10716629	1.10716629	1.10716629	1.01847076	1.00000286	1.00000286	1.00000286	1.00000381
1.00000286	1.00000286	1.00000191	1.00000286	1.00000286	1.00000286	1.00000191	1.00000095	1.00000286	0.99999928
0.99999857	1.00000286	1.00000191	1.00000191	1.00000095	1.00000191	1.00000381	1.00000381	1.00000286	1.00000286
1.00000095	1.00000095	1.00000000	1.00000095	1.00000000	1.00000000	1.00000191	1.00000381	1.00000191	1.00000095
0.99999911	0.99999833	1.00000095	1.00000191	0.99999958	1.00000000	1.00000477	1.00000191	1.00000191	0.99999982
1.00000191	1.00000191	1.00000381	1.00000000	1.00000191	1.00000191	1.00000191	1.00000191	1.00000095	1.00000000
1.00000286	1.00000191	1.00000191	1.00000286	1.00000000	1.00000095	1.00000095	1.00000095	1.00000000	1.00000286
1.00000000	1.00000000	1.00000000	1.00000000						

-----SOURCE VECTOR POP(I,1) (NEUTRONS PER STATE)-----

0.0	1.036E-03	2.166E-03	4.067E-03	6.959E-03	1.093E-02	1.596E-02	2.184E-02	2.821E-02	3.466E-02
4.071E-02	4.598E-02	5.017E-02	5.308E-02	5.468E-02	5.501E-02	5.420E-02	5.242E-02	4.990E-02	4.682E-02
4.338E-02	3.975E-02	3.607E-02	3.246E-02	2.898E-02	2.570E-02	2.266E-02	1.987E-02	1.734E-02	1.508E-02
1.306E-02	1.128E-02	9.707E-03	8.335E-03	7.142E-03	6.106E-03	5.212E-03	4.442E-03	3.780E-03	3.213E-03
2.728E-03	2.313E-03	1.960E-03	1.660E-03	1.405E-03	1.188E-03	1.004E-03	8.480E-04	7.161E-04	6.044E-04
5.100E-04	4.302E-04	3.628E-04	3.058E-04	2.578E-04	2.173E-04	1.831E-04	1.542E-04	1.299E-04	1.094E-04
9.214E-05	7.759E-05	6.533E-05	5.500E-05	4.630E-05	3.898E-05	3.281E-05	2.762E-05	2.325E-05	1.956E-05
1.647E-05	1.386E-05	1.166E-05	9.815E-06	8.260E-06	6.951E-06	5.849E-06	4.922E-06	4.142E-06	3.485E-06
2.933E-06	2.468E-06	2.077E-06	1.747E-06	1.470E-06	1.237E-06	1.041E-06	8.759E-07	7.370E-07	6.202E-07
5.218E-07	4.391E-07	3.694E-07	3.108E-07	2.616E-07	2.201E-07	1.852E-07	1.558E-07	1.311E-07	1.103E-07
9.281E-08	7.809E-08	6.570E-08	5.528E-08	4.652E-08	3.914E-08	3.293E-08	2.771E-08	2.331E-08	1.962E-08
1.651E-08	1.389E-08	1.168E-08	9.832E-09	8.272E-09	6.960E-09	5.856E-09	4.927E-09	4.146E-09	3.488E-09

GENERATING ROUTINE IS BEING CALLED FOR 8 ITERATIONS BEGINNING AT TIME DDT = 6.644E-12 SECONDS.
DDT IS DEFINED FOR VIRTUAL STATE 16 FOR WHICH THE DECAY CONSTANT IS 2.352E 08.

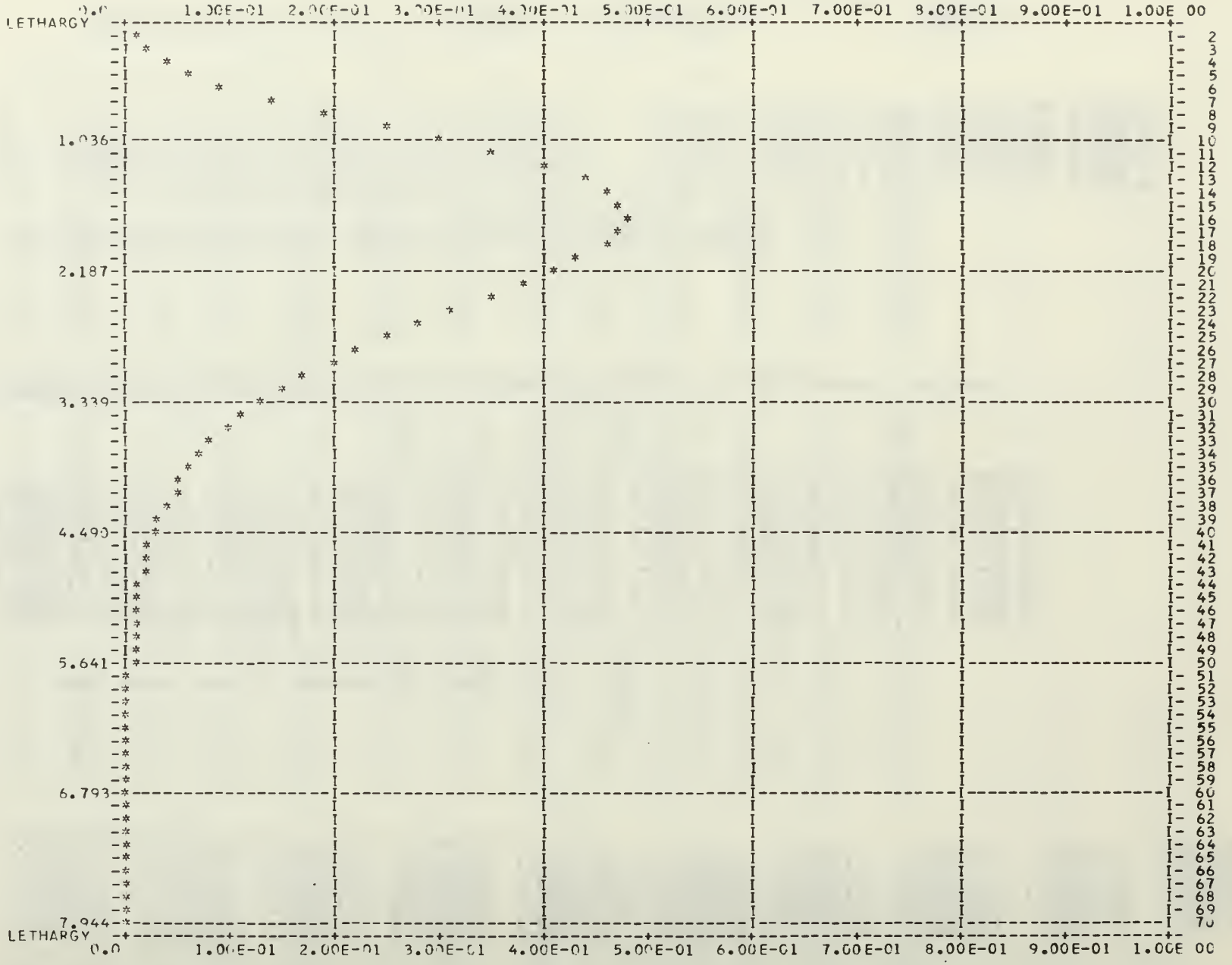
---AT OPERATING ITERATION NO. 1 AND TIME = 0.0 + 0.0 SECONDS,
THE NEUTRON DENSITY (LETHARGY) VECTOR IS WRITTEN BEGINNING WITH VIRTUAL STATE 1.

1	0.0	9.001E-03	1.881E-02	3.533E-02	6.037E-02	9.490E-02	1.386E-01	1.897E-01	2.451E-01	3.010E-01
11	3.536E-01	3.994E-01	4.357E-01	4.611E-01	4.750E-01	4.778E-01	4.707E-01	4.554E-01	4.334E-01	4.067E-01
21	3.768E-01	3.453E-01	3.133E-01	2.819E-01	2.517E-01	2.232E-01	1.968E-01	1.726E-01	1.507E-01	1.310E-01
31	1.134E-01	9.794E-02	8.431E-02	7.240E-02	6.203E-02	5.304E-02	4.527E-02	3.858E-02	3.283E-02	2.790E-02
41	2.369E-02	2.009E-02	1.703E-02	1.442E-02	1.220E-02	1.032E-02	8.720E-03	7.366E-03	6.220E-03	5.250E-03
51	4.430E-03	3.737E-03	3.151E-03	2.657E-03	2.239E-03	1.887E-03	1.590E-03	1.339E-03	1.128E-03	9.503E-04
61	8.003E-04	6.739E-04	5.674E-04	4.777E-04	4.022E-04	3.386E-04	2.850E-04	2.399E-04	2.019E-04	1.699E-04
71	0.0									

ABSORBING STATE POPULATIONS 0.0 0.0 0.0 0.0

MEAN ENERGY (DENSITY AVERAGED) = 1.9675E 06
R. M. S. ENERGY = 2.4947E 06
RELATIVE STANDARD DEVIATION = 7.7955E-01

MEAN VELOCITY = 1.7961E 09
R. M. S. VELOCITY = 1.9405E 09
RELATIVE STANDARD DEVIATION = 4.0886E-01



NT= 1 NTIME= 1 IPEAK= 17 ZA= 0.378E 00 ZX= 0.852E-01

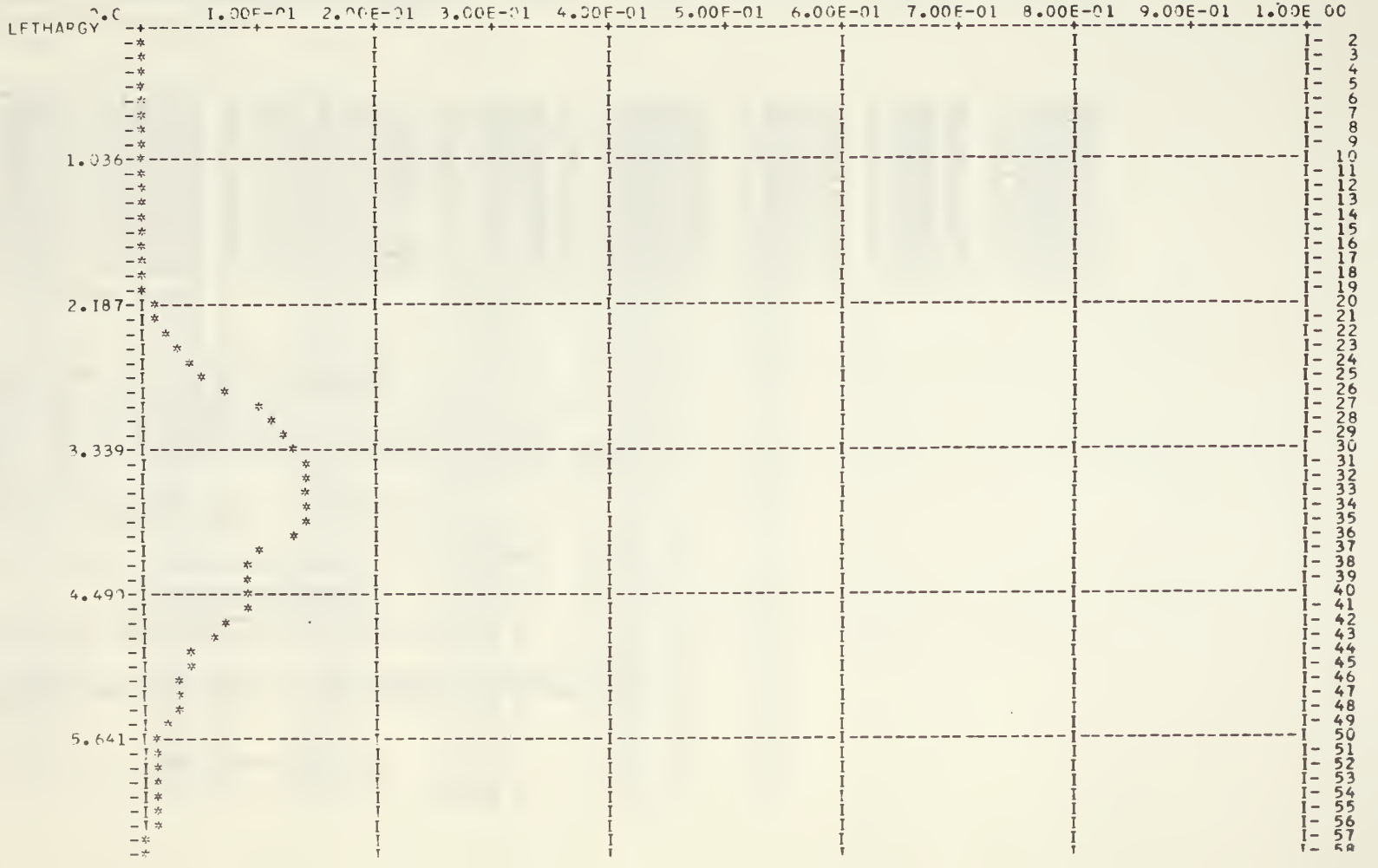
---AT OPERATING ITERATION NO. 24 AND TIME = 0.0 + 0.493E-07 SECONDS,
THE NEUTRON DENSITY (LETHARGY) VECTOR IS WRITTEN BEGINNING WITH VIRTUAL STATE 1.

1	0.0	2.316E-12	2.248E-11	1.452E-10	7.690E-10	4.846E-09	1.546E-08	6.094E-08	2.002E-07	8.686E-07
11	2.294E-06	6.712E-06	1.604E-05	5.044E-05	1.271E-04	2.939E-04	5.510E-04	8.964E-04	2.411E-03	6.216E-03
21	1.266E-02	1.968E-02	2.619E-02	4.193E-02	5.100E-02	7.453E-02	9.663E-02	1.135E-01	1.243E-01	1.289E-01
31	1.384E-01	1.405E-01	1.397E-01	1.382E-01	1.371E-01	1.262E-01	9.535E-02	9.179E-02	8.912E-02	8.741E-02
41	8.619E-02	7.361E-02	5.613E-02	4.238E-02	3.525E-02	3.205E-02	3.059E-02	2.977E-02	1.971E-02	1.116E-02
51	9.765E-03	9.089E-03	8.670E-03	8.328E-03	7.316E-03	5.622E-03	2.097E-03	1.476E-03	1.273E-03	1.149E-03
61	1.047E-03	7.177E-04	3.907E-04	3.665E-04	3.197E-04	2.738E-04	2.334E-04	1.987E-04	1.621E-04	1.425E-04
71	4.026E-06									

ABSCRBING STATE POPULATIONS 4.026E-06 5.516E-02 4.070E-01 2.678E-01

MEAN ENERGY (DENSITY AVERAGED) = 3.0153E 05
R. M. S. ENERGY = 3.7370E 05
RELATIVE STANDARD DEVIATION = 7.3212E-01

MEAN VELOCITY = 7.1180E 08
R. M. S. VELOCITY = 7.5964E 08
RELATIVE STANDARD DEVIATION = 3.7274E-01



---- A MODS CALCULATON ----

EXAMPLE NUMBER 3
STUDY OF SLOWING DOWN SPECTRA IN REPRESENTATIVE FAST MULTIPLYING ASSEMBLY. FISSION SOURCE - DELTA FUNCTION IN TIME.

THE MULTIPLICATION CONSTANT OF THE SYSTEM IS
****
* K = 0.981699E 00 *
****

ESTIMATE OF K FROM TRUNCATED DISTRIBUTION---- 0.969340

THE CENTRAL CORE FLUX-AVERAGED ENERGY IS 8.912E 05 EV.
THE LEAKAGE FLUX-AVERAGED ENERGY IS 1.454E 06 EV.

AT 3.113E-07 SECONDS--
9.899 PERCENT OF THE NEUTRONS HAVE SUFFERED NON-FISSION CAPTURE,
51.251 PERCENT OF THE NEUTRONS HAVE LEAKED FROM THE SYSTEM,
37.870 PERCENT OF THE NEUTRONS HAVE CAUSED FISSION,
0.002 PERCENT OF THE NEUTRONS HAVE ENERGY BELOW 1.18E 01 EV,
1.183 PERCENT ARE STILL SLOWING DOWN,
-0.125 PERCENT ARE LOST FROM THE SYSTEM, AND
0.004 PERCENT HAVE BEEN BYPASSED BY THE ARRAY.

**** FINAL STATE VECTOR

0.0	1.304E-57	4.212E-54	6.288E-51	5.582E-48	1.952E-44	1.258E-42	3.354E-40	6.816E-38	6.910E-35
2.413E-33	2.079E-31	1.454E-29	5.370E-27	2.546E-25	1.089E-23	3.346E-22	7.614E-21	3.139E-18	3.414E-16
8.618E-15	1.273E-13	1.316E-12	3.500E-11	1.668E-10	1.030E-09	5.686E-09	2.740E-08	1.144E-07	3.835E-07
1.260E-06	3.652E-06	9.420E-06	2.171E-05	0.0	9.349E-06	2.027E-05	4.136E-05	7.197E-05	1.154E-04
1.753E-04	2.503E-04	3.564E-04	4.710E-04	5.951E-04	7.155E-04	8.178E-04	8.904E-04	8.787E-04	6.287E-04
6.224E-04	6.042E-04	5.797E-04	5.508E-04	5.081E-04	8.416E-04	4.559E-04	2.551E-04	1.488E-04	1.018E-04
8.527E-05	6.643E-05	2.532E-05	1.761E-05	1.250E-05	9.827E-06	8.442E-06	7.573E-06	6.048E-06	5.666E-06
1.202E-05	1.147E-05	9.904E-06	8.425E-06	7.074E-06	5.725E-06	4.903E-06	4.167E-06	3.539E-06	3.005E-06
2.549E-06	2.086E-06	1.695E-06	1.465E-06	1.246E-06	1.058E-06	8.984E-07	7.622E-07	6.209E-07	5.245E-07
4.457E-07	3.781E-07	3.208E-07	2.721E-07	2.282E-07	1.853E-07	1.580E-07	1.342E-07	1.139E-07	9.658E-08
8.187E-08	6.784E-08	5.668E-08	4.796E-08	4.652E-08	3.914E-08	3.293E-08	2.771E-08	2.331E-08	1.962E-08
1.651E-08	1.389E-08	1.168E-08	9.832E-09	8.272E-09	6.960E-09	5.856E-09	4.927E-09	4.146E-09	3.488E-09
1.529E-05	9.899E-02	5.125E-01	3.787E-01						

**** FINAL CORE FLUX VECTOR

0.0	2.136E-03	4.551E-03	8.581E-03	1.471E-02	2.378E-02	3.464E-02	4.833E-02	6.284E-02	8.237E-02
9.988E-02	1.177E-01	1.299E-01	1.529E-01	1.739E-01	1.873E-01	1.897E-01	1.869E-01	2.209E-01	2.666E-01
2.905E-01	2.910E-01	2.819E-01	3.134E-01	3.081E-01	3.426E-01	3.556E-01	3.561E-01	3.497E-01	3.273E-01
3.189E-01	3.078E-01	2.976E-01	2.873E-01	2.774E-01	2.493E-01	1.881E-01	1.814E-01	1.753E-01	1.696E-01
1.643E-01	1.434E-01	1.207E-01	1.012E-01	8.690E-02	7.601E-02	6.766E-02	6.124E-02	4.464E-02	2.670E-02
2.271E-02	1.947E-02	1.697E-02	1.504E-02	1.276E-02	1.358E-02	5.818E-03	3.112E-03	2.047E-03	1.617E-03
1.409E-03	8.930E-04	3.889E-04	2.969E-04	2.343E-04	1.902E-04	1.559E-04	1.279E-04	9.552E-05	7.926E-05
1.195E-05	1.003E-05	8.057E-06	6.440E-06	5.081E-06	3.913E-06	3.139E-06	2.508E-06	2.004E-06	1.600E-06
1.277E-06	9.791E-07	7.671E-07	6.173E-07	4.933E-07	3.940E-07	3.145E-07	2.510E-07	1.916E-07	1.527E-07
1.219E-07	9.729E-08	7.764E-08	6.194E-08	4.878E-08	3.750E-08	2.999E-08	2.394E-08	1.910E-08	1.524E-08
1.215E-08	9.449E-09	7.389E-09	5.889E-09	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

**** FINAL SURFACE FLUX VECTOR

0.0	8.726E-03	1.786E-02	3.232E-02	5.368E-02	7.454E-02	1.016E-01	1.356E-01	1.682E-01	1.939E-01
2.115E-01	2.377E-01	2.499E-01	2.692E-01	2.808E-01	2.888E-01	2.793E-01	2.628E-01	3.000E-01	3.524E-01
3.754E-01	3.668E-01	3.434E-01	3.363E-01	2.977E-01	3.275E-01	3.356E-01	3.295E-01	3.139E-01	2.665E-01
2.423E-01	2.271E-01	2.122E-01	1.976E-01	1.827E-01	1.387E-01	8.985E-02	8.382E-02	7.832E-02	7.329E-02
6.845E-02	5.612E-02	4.538E-02	3.742E-02	3.134E-02	2.647E-02	2.253E-02	1.919E-02	1.129E-02	6.315E-03
5.134E-03	4.186E-03	3.451E-03	2.894E-03	2.489E-03	3.284E-03	1.367E-03	6.741E-04	4.003E-04	2.910E-04
2.388E-04	1.226E-04	4.132E-05	2.854E-05	2.081E-05	1.593E-05	1.241E-05	9.706E-06	6.928E-06	5.463E-06
1.275E-06	1.011E-06	7.679E-07	5.860E-07	4.307E-07	3.092E-07	2.344E-07	1.770E-07	1.336E-07	1.008E-07
7.598E-08	4.821E-08	3.179E-08	2.418E-08	1.826E-08	1.379E-08	1.039E-08	7.837E-09	5.603E-09	4.216E-09

TABLE OF MOMENTS OF DISTRIBUTIONS
(UNITS ARE MICROSECONDS)

	ABSORBING STATE MOMENTS				TRUNCATION CORRECTIONS			
N	FISSION	LEAKAGE	CAPTURE	TOTAL	FISSION	LEAKAGE	CAPTURE	TOTAL
1	4.7045E-02	3.3793E-02	7.5464E-02	4.3768E-02	4.9540E-03	1.5838E-03	1.1142E-02	3.9357E-03
2	7.0554E-03	3.5977E-03	1.3948E-02	6.0553E-03	2.2493E-03	6.6866E-04	5.4448E-03	1.7632E-03
RSD	1.4791E 00	1.4664E 00	1.2038E 00	1.4700E 00				

INTERPOLATED DISTRIBUTIONS
DTI= 2.0E-09 SECONDS

N	TIME	FISSION	LEAKAGE	CAPTURE	TOTAL	N
1	5.000E-10	5.536E 07	5.869E 07	2.073E 07	5.188E 07	1
2	1.000E-09	5.323E 07	5.662E 07	2.045E 07	5.008E 07	2
3	1.500E-09	5.111E 07	5.455E 07	2.016E 07	4.829E 07	3
4	2.000E-09	4.898E 07	5.248E 07	1.988E 07	4.649E 07	4
5	2.500E-09	4.685E 07	5.040E 07	1.959E 07	4.469E 07	5
6	3.000E-09	4.155E 07	4.530E 07	1.887E 07	4.027E 07	6
7	3.500E-09	4.013E 07	4.378E 07	1.864E 07	3.895E 07	7
8	4.000E-09	3.860E 07	4.226E 07	1.842E 07	3.764E 07	8
9	4.500E-09	3.468E 07	3.835E 07	1.782E 07	3.424E 07	9
10	5.000E-09	3.356E 07	3.721E 07	1.763E 07	3.325E 07	10
11	5.500E-09	3.244E 07	3.606E 07	1.744E 07	3.226E 07	11
12	6.000E-09	2.944E 07	3.300E 07	1.692E 07	2.961E 07	12
13	6.500E-09	2.859E 07	3.212E 07	1.676E 07	2.884E 07	13
14	7.000E-09	2.775E 07	3.124E 07	1.659E 07	2.808E 07	14
15	7.500E-09	2.690E 07	3.036E 07	1.642E 07	2.731E 07	15
16	8.000E-09	2.475E 07	2.811E 07	1.598E 07	2.536E 07	16
17	8.500E-09	2.410E 07	2.741E 07	1.582E 07	2.476E 07	17
18	9.000E-09	2.345E 07	2.672E 07	1.567E 07	2.416E 07	18
19	9.500E-09	2.173E 07	2.488E 07	1.527E 07	2.257E 07	19
20	1.000E-08	2.122E 07	2.432E 07	1.513E 07	2.208E 07	20
21	1.200E-08	1.850E 07	2.132E 07	1.435E 07	1.949E 07	21
22	1.400E-08	1.636E 07	1.890E 07	1.363E 07	1.740E 07	22
23	1.600E-08	1.464E 07	1.691E 07	1.297E 07	1.567E 07	23
24	1.800E-08	1.285E 07	1.479E 07	1.217E 07	1.384E 07	24
25	2.000E-08	1.176E 07	1.346E 07	1.161E 07	1.269E 07	25
26	2.200E-08	1.083E 07	1.231E 07	1.109E 07	1.170E 07	26
27	2.400E-08	1.004E 07	1.131E 07	1.060E 07	1.083E 07	27
28	2.600E-08	9.343E 06	1.043E 07	1.014E 07	1.007E 07	28
29	2.800E-08	8.734E 06	9.655E 06	9.710E 06	9.392E 06	29
30	3.000E-08	8.165E 06	8.921E 06	9.280E 06	8.751E 06	30
31	3.200E-08	7.666E 06	8.276E 06	8.884E 06	8.187E 06	31
32	3.400E-08	7.364E 06	7.886E 06	8.637E 06	7.844E 06	32
33	3.600E-08	6.853E 06	7.228E 06	8.204E 06	7.263E 06	33
34	3.800E-08	6.393E 06	6.637E 06	7.799E 06	6.740E 06	34
35	4.000E-08	6.176E 06	6.360E 06	7.599E 06	6.492E 06	35
36	4.200E-08	5.791E 06	5.870E 06	7.240E 06	6.053E 06	36
37	4.400E-08	5.602E 06	5.632E 06	7.058E 06	5.838E 06	37
38	4.600E-08	5.274E 06	5.220E 06	6.738E 06	5.465E 06	38
39	4.800E-08	4.971E 06	4.844E 06	6.436E 06	5.122E 06	39
40	5.000E-08	4.825E 06	4.664E 06	6.286E 06	4.957E 06	40
41	5.200E-08	4.561E 06	4.343E 06	6.014E 06	4.660E 06	41
42	5.400E-08	4.431E 06	4.185E 06	5.877E 06	4.514E 06	42
43	5.600E-08	4.199E 06	3.908E 06	5.631E 06	4.255E 06	43
44	5.800E-08	3.983E 06	3.652E 06	5.399E 06	4.014E 06	44
45	6.000E-08	3.877E 06	3.528E 06	5.282E 06	3.897E 06	45
46	6.200E-08	3.684E 06	3.305E 06	5.068E 06	3.684E 06	46
47	6.400E-08	3.588E 06	3.195E 06	4.963E 06	3.578E 06	47
48	6.600E-08	3.416E 06	2.999E 06	4.765E 06	3.389E 06	48
49	6.800E-08	3.328E 06	2.901E 06	4.665E 06	3.294E 06	49
50	7.000E-08	3.173E 06	2.728E 06	4.488E 06	3.126E 06	50

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13. ABSTRACT

This document provides users' information for a computer code, MOD-5, which calculates the time and energy dependent evolution of the neutron density in homogeneous media following initiation of a pulsed neutron source of arbitrary energy distribution. The code is based on a discrete stochastic model of the neutron slowing down process developed by the author. Copies of the code and associated computer software are available through the Argonne Code Center, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Multigroup						
Neutron						
Slowing-Down						
Stochastic						
Computer Code						

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